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AEFA

PRELIMINARY AIRWORTHINESS EVALUATION OF THE UH-60A/ESSS WITH HELLFIRE LAUNCHER INSTALLED

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FINAL REPORT

Approved for public release; distribution unlimited.

U S ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523 - 5000

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A Preliminary Airworthiness Evaluation of the UH-60A helicopter (S/N 84-23953) configured with the External Stores Support System (ESSS) and 16 HELLFIRE (4 HMMS) missiles installed was conducted by the U.S. Army Aviation Engineering Flight Activity. The test was conducted at the Sikorsky Flight Test Facility at West Palm Beach, Florida (elevation 28 feet). A total of 16.2 productive hours during 18 flights were flown between 21 May and 3 June 1987. Tests were conducted to determine handling qualities and performance of the UH-60A in the 16 HELLFIRE (4 HMMS) missile system configuration at an average mission gross weight of 17,000 pounds. The handling qualities of the UH-60A with the 16 HELLFIRE (4 HMMS) missile system installed were essentially unchanged from those previously reported for the UH-60A in the normal utility configuration. The equivalent flat plate area of the 16 HELLFIRE (4 HMMS) missile system was determined to be 11 square feet over that of the UH-60A in the ESSS only configuration. One miscellaneous observation was made regarding the initial installation and fit of the production ESSS fairings. Keywords: Helicopters; Air

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INTRODUCTION

BACKGROUND

1. The U.S. Army is investigating the potential of the UH-60A, Black Hawk, helicopter for carrying the HELLFIRE missiles on the External Stores Support System (ESSS). This capability will provide the Army with an additional anti-tank weapon platform. In September 1984, Sikorsky Aircraft Division of United Technologies Corporation and Rockwell International, Inc., were awarded contracts by the U.S. Army Aviation Systems Command (AVSCOM) to develop and demonstrate the feasibility of the UH-60A HELLFIRE system. AVSCOM tasked the U.S. Army Aviation Engineering Flight Activity (AEFA) (ref 1, app A) to plan, conduct and report on a Preliminary Airworthiness Evaluation (PAE) of the UH-60A with the HELLFIRE missile system installed.

TEST OBJECTIVE

2. The objectives of this evaluation were to determine the airworthiness of the HELLFIRE installation and whether any limitations to the UH-60A flight envelope exist in order to substantiate the issuance of an airworthiness release for follow-on testing.

DESCRIPTION

3. The UH-60A, Black Hawk, helicopter is a twin-turbine, single main rotor helicopter capable of transporting cargo, 11 combat troops and weapons during day, night, visual meteorological conditions, and instrument meteorological conditions. Conventional wheel-type landing gear are provided. The main and tail rotors are both four-bladed. Manual main rotor blade and tail pylon folding capabilities are provided for air transportability. A movable horizontal stabilator is located on the lower portion of the tail rotor pylon. The helicopter is powered by two T700-GE-700 turboshaft engines each having an uninstalled thermodynamic rating (30 minute) of 1553 shaft horsepower (shp) (power turbine speed of 20,900 rpm) at sea level, standard day static conditions. Installed dual engine power is transmission limited to 2828 shp.

4. The UH-60A helicopter (USA S/N 84-23953) used for this test was a production Black Hawk which incorporates the External Stores Support System fixed provisions and fairings, the reoriented production airspeed probes and the modified production stabilator schedule. A more detailed description of the UH-60A is contained in the Prime Item Development Specification (PIDS) (ref 2), the operator's manual (ref 3), and appendix B. The test helicopter, configured with the HELLFIRE missile system, is depicted in photo 1.

Photo 1. UH-60A Helicopter with ESSS Wings and 4 HMMS Installed

5. The ESSS consists of the airframe fixed provisions and the removable external stores subsystem. The ESSS is designed to enable the UH-60A to carry external stores such as auxiliary fuel tanks or various weapon subsystems such as the HELLFIRE missile system. The UH-60A HELLFIRE system consists of UH-60A HELLFIRE Missile Equipment (UH-60A HME), aircraft fixed provisions, and support equipment. The UH-60A HME is a kit, which consists of the necessary electronics, electrical harnesses, hardware, and system controls required to interface with and manage the HELLFIRE Modular Missile System (HMMS). Each HMMS consists of four AGM-114A HELLFIRE missiles and a launcher assembly which mounts on the UH-60A ESSS pylons. The UH-60A ESSS can accommodate up to four HMMS (two on each side) for a total of 16 HELLFIRE missiles.

6. The ESSS stores jettison system was fully operational, the HELLFIRE HMMS was installed with 16 inert HELLFIRE Missiles, and the UH-60A HME kit was not installed in the test aircraft. A more detailed description of the HELLFIRE missile system is included in references 4 and 5, appendix A, and appendix B.

TEST SCOPE

7. The PAE was conducted by AEFA personnel at the Sikorsky Flight Test Facility at West Palm Beach, Florida (elevation 28 feet). A total of 16.2 productive hours during 18 flights were flown between 21 May and 3 June 1987. The contractor provided all maintenance and logistical support of the test aircraft to include test instrumentation and data reduction support. Tests were conducted to determine handling qualities and performance of the UH-60A in the 16 HELLFIRE (4HMMS) missile system configuration at an average mission gross weight of 17,000 pounds and an average longitudinal center of gravity (cg) at fuselage station 350.0. Results were compared to those published in the Airworthiness and Flight Characteristics (A&FC) test of the UH-60A helicopter (ref 6, app A), A&FC test of the UH-60A with the prototype ESSS (ref 7), the requirements of the Critical Item Development Specification for a UH-60A HELLFIRE System (ref 3), and MIL-H-8501A (ref 8). Flight restrictions and operating limitations observed througout the evaluation are contained in the operator's manual (ref 3) and the airworthiness release issued by AVSCOM (ref 9). Testing was conducted in accordance with the approved test plan (ref 10) at the conditions presented in tables 1 and 2.

TEST METHODOLOGY

8. The flight test data were recorded by hand from test instrumentation displayed in the cockpit, by on-board magnetic tape recording equipment and via telemetry to the Sikorsky Real-Time Acquisition and Processing of In-flight Data system. A detailed listing of test instrumentation is contained in appendix C. Flight test techniques and data reduction procedures are described in appendix D.

Table 1. Level Flight Performance Test Conditions[1]

Average Gross Weight (lb)	Average Thrust Coefficient (x10^4)	Average Longitudinal Center of Gravity (FS)[2]	Average Density Altitude (ft)	Airspeed Range (KTAS)[3]	Configuration
17,010 16,810 16,880	70.06 79.91 89.78	350.1 349.2 349.5	5,290 9,330 12,350	46 to 154 50 to 154 52 to 146	ESSS Only Installed
16,950 16,850 16,980	69.91 79.96 90.16	350.0 349.6 350.1	5,250 9,110 12,190	45 to 149 48 to 146 51 to 139	ESSS with HELLFIRE (4HMMS) Installed

NOTE:

[1]Tests conducted with doors and windows closed, stability augmentation system (SAS) ON, pitch bias actuator (PBA) centered and locked, and engine bleed air systems OFF. Main rotor speed of 258 referred rpm, approximate mid lateral center of gravity location.
[2]FS: Fuselage station.
[3]KTAS: Knots true airspeed.

Table 2. Handling Qualities Test Conditions[1]

Type of Test	Average Gross Weight (lb)	Average Longitudinal Center of Gravity (FS)[2]	Average Density Altitude (ft)	Trim Calibrated Airspeed (kt)	Remarks	
Control Positions in Trimmed Forward Flight[3]	16,900	349.6	5,290 to 12,350	42 to 142	ESSS Only Installed	
	16,920	349.9	5,250 to 12,190	42 to 137	ESSS with HELLFIRE (4HMMS) Installed	
Static Longitudinal Stability[3]	16,900	350.0	6,220	100 and 134	Level Flight	
Static Lateral-Directional Stability	16,900	350.0	6,400	100 and 132	Level Flight	
Maneuvering Stability[3]	16,940	350.1	7,700	100 and 129	Left and Right Steady Turns	
	17,100	350.8	6,470	98 and 131	Symmetrical Pull-Ups and Pushovers	
Dynamic Stability[3]	17,080	350.4	6,500	100 and 134	Control Pulses	SAS[4] and FPS[5] ON and SAS and FPS OFF
	17,200	350.3	6,300	100 and 132	Releases from Sideslip	
	16,680	349.1	6,400	100 and 133	Long-Term Response	
Low Speed Flight	17,040	351.0	1,400	0 to 40 (KTAS)[6]	Azimuths: 0°, 90°, 180°, 270°, 315°. Wheel Height 30 feet	
Simulated Single-Engine Failures From Dual-Engine Flight[3]	17,080	350.7	7,320	82 to 133	Level Flight	
	16,900	350.0	7,820	82	IRP[7] Climb	

NOTES:

[1]Test conducted with External Stores Support System (ESSS) only and 4 HELLFIRE Modular Missile system (HMMS) installed with the automatic flight control system (AFCS) ON unless otherwise indicated, pitch bias actuator (PBA) centered and locked. Rotor speed of 258 rpm, approximate mid lateral center of gravity location.
[2]FS: Fuselage station.
[3]Test conducted in ball-centered flight.
[4]SAS: Stability Augmentation System.
[5]FPS: Flight Path Stabilization.
[6]KTAS: Knots true airspeed.
[7]IRP: Intermediate rated power.

RESULTS AND DISCUSSION

GENERAL

9. Testing was conducted to determine the handling qualities and performance effects of the HELLFIRE missile system on the UH-60A helicopter. The handling qualities of the UH-60A with the 16 HELLFIRE (4 HMMS) missile system installed were essentially unchanged from those previously reported for the UH-60A in the normal utility configuration. The equivalent flat plate area of the 16 HELLFIRE (4 HMMS) missile system was determined to be 11 square feet over that of the UH-60A in the External Stores Support System (ESSS) only configuration.

LEVEL FLIGHT PERFORMANCE

10. Limited performance flight testing was conducted to determine the performance differences between the UH-60A helicopter in the ESSS only configuration and with the HELLFIRE missile system installed. Level flight performance tests were conducted in ball-centered flight at three conditions for both configurations listed in table 1 to determine the power required at various airspeeds. Nondimensional level flight test results are presented in figures 1 and 2, appendix E. Dimensional test results for the UH-60A in the ESSS only configuration are presented in figures 3 through 5, and with the HELLFIRE missile system installed in figures 6 through 8. Installation of the 16 HELLFIRE (4 HMMS) missile system resulted in an increase in equivalent flat plate area (ΔF_e) of 11.0 square feet over the ESSS only configuration.

11. Performance data with the UH-60A in the normal utility configuration at two comparable test conditions are available from AEFA Project No. 86-10, a previous AEFA program flown using the same aircraft (ref 11). The drag increase between the UH-60A in the normal utility configuration and the ESSS only configuration was 10.0 square feet ΔF_e. Figures 9 and 10 show the performance data at two thrust coefficients for the ESSS only configuration and the corresponding curves for the normal utility configuration derived from reference 11.

HANDLING QUALITIES

General

12. A limited handling qualities evaluation of the UH-60A configured with the HELLFIRE missile system was conducted to determine any changes caused by this installation. Handling qualities of

the UH-60A with the HELLFIRE missile system installed were quantitatively and qualitatively evaluated and found to be essentially the same as the UH-60A in the normal utility configuration.

Control Positions in Trimmed Forward Flight

13. Control positions in trimmed, ball-centered, forward flight were obtained in conjunction with level flight performance testing at the conditions presented in table 2. Representative level flight data are presented in figures 11 through 16. The variation of longitudinal control position with airspeed during trimmed level flight generally required increased forward cyclic control with increased airspeed, similar to that previously reported in reference 7, appendix A. Control position trends for a UH-60A with fixed-provision fairings only (normal utility configuration), the ESSS only, and the HELLFIRE missile system installed are similar. However, pitch attitudes during level flight varied as a function of change in equivalent flat plate area. Below 100 knots calibrated airspeed (KCAS), the UH-60A with the ESSS only installed flew at a pitch attitude of approximately 2° more nose-down than the UH-60A with fixed-provision fairings only. The UH-60A with the HELLFIRE missile system installed flew at a pitch attitude of approximately 1° more nose-down than the UH-60A with the ESSS only. Above 100 KCAS, pitch attitude differences were significantly greater. Control positions in trimmed forward flight both with and without the HELLFIRE missile system installed are satisfactory. The following CAUTION should be incorporated into the operator's manual.

CAUTION

> Prior to installation of the HELLFIRE missile system, insure that modified input modules (P/N 7035108001-046) have been installed in the aircraft. The increased nose-down pitch attitudes during level flight when the HELLFIRE missile system is installed may result in oil foaming and inadequate lubrication without the required gearbox modification.

Static Longitudinal Stability

14. The static longitudinal stability characteristics of the UH-60A configured with the HELLFIRE missile system were evaluated at the conditions presented in table 2. The helicopter was stabilized in ball-centered flight at the desired trim airspeed and flight condition. The collective control was held fixed

while airspeed was varied approximately ± 20 knots about trim in 5 knot increments. Test results are presented in figure 17, appendix E. The static longitudinal stability (as indicated by the variation of longitudinal cyclic control position with airspeed) was positive (forward longitudinal cyclic control position with increased airspeed) and similar to that reported in reference 7, appendix A. However, longitudinal cyclic control position variation about trim was so small that cyclic position changes were imperceptible. Control force cues of longitudinal cyclic control displacement about trim were weak, but sufficient for airspeed control within ± 2 knots (Handling Qualities Rating Scale (HQRS) 3). The static longitudinal stability characteristics of the UH-60A configured with the HELLFIRE missile system were essentially the same as the UH-60A in the normal utility configuration, are satisfactory and met the requirements of the PIDS.

Static Lateral-Directional Stability

15. The static lateral-directional stability characteristics of the UH-60A configured with the HELLFIRE missile system were evaluated at the conditions presented in table 2. The helicopter was stabilized in ball-centered flight at the desired trim airspeed and flight condition. With the collective control held fixed, the aircraft was then stabilized at incremental sideslip angles up to limit sideslip angle on each side of trim while maintaining a zero turn rate at the trim airspeed. Representative data are presented in figure 18, appendix E.

16. Static directional stability (as indicated by the variation of directional control position with sideslip angle) was positive (increased left directional control required with increased right sideslip). The directional control variation with sideslip was essentially linear, similar to findings reported in reference 7, appendix A. The directional stability characteristics of the UH-60A configured with the HELLFIRE missile system were essentially the same as the UH-60A in the normal utility configuration, are satisfactory, and met the requirements of MIL-H-8501A.

17. Dihedral effect (as indicated by the variation of lateral cyclic control position with sideslip angle) was positive (increased right cyclic control with increased right sideslip) and essentially linear. There were no discontinuities in force or position cues. Similar results were previously reported in reference 7. The dihedral effect of the UH-60A configured with the HELLFIRE missile system was essentially the same as the UH-60A in the normal utility configuration, is satisfactory, and met the requirements of MIL-H-8501A.

18. Sideforce characteristics (as indicated by the variation in bank angle with sideslip) were positive (increased right bank angle with increased right sideslip) and good out-of-trim cues were evident. The sideforce characteristics of the UH-60A configured with the HELLFIRE missile system were essentially the same as the UH-60A in the normal utility configuration, are satisfactory, and met the requirements of MIL-H-8501A.

19. A pitch-due-to-sideslip coupling was evident in all test conditions. Generally, the longitudinal cyclic position versus sideslip required increased forward longitudinal cyclic control with increased right sideslip. The pitch-due-to-sideslip coupling exhibited was not considered objectionable and was similar to that previously reported in reference 7.

Maneuvering Stability

20. The maneuvering stability characteristics of the UH-60A configured with the HELLFIRE missile system were evaluated at the conditions presented in table 2. The maneuvering stability tests were accomplished by initially stabilizing the helicopter in ball-centered level flight at the trim airspeed and then incrementally increasing the normal acceleration (g) by increasing the bank angle in left and right turns. Constant collective control position was maintained during the maneuvers and the pilot attempted to maintain constant airspeed. Symmetrical pull-ups and pushovers were conducted by alternately climbing and diving the helicopter to achieve varying g while the aircraft was passing through the trim altitude at the desired airspeed. Test results are presented in figures 19 through 22, appendix E.

21. The stick-fixed maneuvering stability (as indicated by the variation of longitudinal cyclic control position with g), was positive (increased aft cyclic control position with increased g). There were no significant differences in the handling qualities characteristics in right or left turns. The variation in longitudinal control position with g was essentially linear, and the lateral cyclic control position remained essentially constant at all bank angles. Longitudinal control force cues were adequate at bank angles greater than 15 degrees. The maneuvering stability characteristics of the UH-60A configured with the HELLFIRE missile system are satisfactory.

Dynamic Stability

General:

22. The dynamic stability characteristics of the UH-60A configured with the HELLFIRE missile system were evaluated at the conditions

presented in table 2. The short-term response was excited in al' control axes by making single-axis, 1 inch pulse inputs which we ield for approximately 0.5 second and by control releases from limit sideslip values. Long-term longitudinal dynamic stability characteristics were evaluated by displacing the aircraft from trim airspeed approximately 10 to 15 knots, smoothly returning the longitudinal control to the trim position, and observing/recording the resultant response. Testing was conducted in calm to light turbulence meteorological conditions, as defined in the Flight Information Handbook (ref 12). Representative time history data are presented in figures 23 through 34, appendix E.

Short-Term Response:

23. The stability augmentation system (SAS) ON short-term response was heavily damped in all axes, decaying to one-half amplitude within one cycle. The SAS OFF short-term response was characterized by strong coupling into the longitudinal axis which rapidly excited the long-term response. An aperiodic and divergent response resulted within 2 to 3 seconds requiring aircraft recovery. However, during SAS OFF flight airspeed was maintained ±10 knots with minimal pilot compensation (HQRS 3). The short-term response of the UH-60A configured with the HELLFIRE missile system was essentially the same as the UH-60A in the normal utility configuration (SAS ON and SAS OFF), is satisfactory, and met the requirements of the PIDS.

24. The SAS ON lateral-directional oscillatory response resulting from steady heading sideslip releases were characterized as heavily damped with a maximum of two small heading overshoots prior to returning to within ±2° of trim heading within 10 to 15 seconds. The SAS OFF lateral-directional oscillatory response was characterized as aperiodic and divergent with an immediate roll away from sideslip and nose-up pitch change. Test limit values of 60° angle of bank and 30° nose-up pitch attitude were reached in 2 to 3 seconds. However, during SAS OFF level flight, the lateral-directional oscillatory response required only small (1/4 inch) infrequent (every 5-7 seconds) lateral cyclic inputs to maintain heading ±5° (HQRS 3). The lateral-directional oscillatory response of the UH-60A configured with the HELLFIRE missile system was essentially the same as the UH-60A in the normal utility configuration (SAS ON and SAS OFF), is satisfactory, and met the requirements of the PIDS.

Long-Term Response:

25. The SAS ON long-term response was heavily damped, returning to trim airspeed within ±1 knot after only two small 5 knot

overshoots. The SAS OFF long-term response was easily excited and characterized as aperiodic and divergent within 2 to 3 seconds. The long-term response of the UH-60A configured with the HELLFIRE missile system was essentially the same as the UH-60A in the normal utility configuration (SAS ON and SAS OFF), is satisfactory, and met the requirements of the PIDS.

Low-Speed Flight Characteristics

26. The low-speed flight characteristics of the UH-60A configured with the HELLFIRE missile system were evaluated at the conditions presented in table 2. Tests were conducted at true airspeeds up to 45 knots in forward and rearward (0° and 180° relative azimuths) and sideward (90°, 270°, and 315° relative azimuths) flight at a wheel height of 30 feet (as measured by the radar altimeter). Surface winds were 5 knots or less and a ground pace vehicle was used as a speed reference. The low speed flight test data are presented in figures 35 through 37, appendix E.

27. Pilot workload (frequency and magnitude of inputs) required to maintain speed, altitude, and heading control during forward and rearward flight was qualitatively assessed as HQRS 3 between 0 and 20 knots true airspeed (KTAS). Above 20 KTAS, the frequency of inputs noticeably decreased, but the overall pilot workload remained HQRS 3. Adequate control margins remained throughout the tested airspeed range during both forward and rearward flight. During forward and rearward flight, the low speed flight characteristics of the UH-60A with the HELLFIRE missile system installed were similar to that of a UH-60A in the normal utility configuration and are satisfactory.

28. During left sideward flight, the lateral cyclic position cues were noticeably weaker than during right sideward flight. Data taken during left sideward flight show a small band of essentially neutral lateral cyclic control position versus airspeed between 15 and 30 KTAS. This anomaly was not perceived by the pilot and was not considered objectionable. Stabilator programming began to occur at approximately 20 KTAS during left sideward flight, while the stabilator remained programmed in the full trailing edge down (40°) position during right sideward flight. During left sideward flight, the frequency of control inputs was very high (almost continuous) in all control axes. Adequate control margins remained throughout this evaluation. During left and right sideward flight, the low speed flight characteristics of the UH-60A with the HELLFIRE missile system installed were similar to that of a UH-60A in the normal utility configuration and are satisfactory.

29. The flight control variations during sideward flight at a relative wind azimuth of 315° were non-linear, but were not objectionable. The non-linearities occurred as the stabilator began to program inconsistently above approximately 20 KTAS. There were adequate control margins throughout the evaluation. Intermittent, variable intensity lateral accelerations referred to as "tail shake" by Sikorsky flight test personnel occurred more frequently and with greater magnitude than during the other wind azimuths evaluated. This is characteristic of the UH-60A in the normal utility configuration and may have been aggravated somewhat by the installation of the HELLFIRE missile system. During sideward flight at a relative wind azimuth of 315°, the low speed characteristics were similar to that of a UH-60A in the normal utility configuration and are satisfactory.

Simulated Single-Engine Failure

30. Simulated single-engine failure from dual-engine flight characteristics of the UH-60A configured with the HELLFIRE missile system were evaluated at the conditions presented in table 2. Representative time histories are presented in figures 38 through 40. The engine failures were simulated by rapidly pulling one engine power control lever from the flight position to the idle position and delaying pilot reaction for a minimum of 2 seconds or until recovery was required, whichever occurred first. There were no differences (handling qualities or failure cues) noted between a "failed" left engine or a "failed" right engine. The simulated engine failures were detected by an audible warning tone, the respective ENG OUT master caution light, a difference in cockpit engine parameters, and a noticeable 2° to 3° left yaw. Other than the yaw excursion, no unusual attitude changes or control forces were observed during the simulated engine failures and the subsequent transition to single-engine flight. The simulated single-engine failure from dual-engine flight characteristics of the UH-60A configured with the HELLFIRE missile system was essentially the same as the UH-60A in the normal utility configuration and are satisfactory.

VIBRATION

31. Vibration characteristics obtained during level flight performance tests are presented as a function of airspeed. Vertical, lateral, and longitudinal acceleration values for frequencies of 1, 4, and 8 per main rotor revolution are shown at the pilot's seat location (figs. 41 through 44) and on the cargo compartment floor at fuselage station 345 (figs. 45 through 48). Both the ESSS only and HELLFIRE missile system installed aircraft

configurations are presented for nominal thrust coefficient (C_T x 10^4) values of 70 and 90. Aircraft vibration characteristics were qualitatively and quantitatively evaluated for the UH-60A configured with the ESSS only and with the HELLFIRE missile system installed as being slightly worse than the UH-60A in the normal utility configuration in that "tail shake" occurred more frequently and with greater magnitude, as previously discussed in paragraph 29.

AIRSPEED CALIBRATION

32. Airspeed calibration tests were conducted to determine the position error of the UH-60A's airspeed system in both the ESSS only configuration and with the HELLFIRE missile system (4 HMMS) installed. The aircraft's pitot-static system was calibrated up to 117 knots indicated airspeed (KIAS) during level flight by use of a calibrated trailing bomb (finned pitot-static system). Data for the normal utility configuration up to 156 KIAS were available from AEFA Project No. 86-10, a previous program flown using the same aircraft (ref 11). Data for the normal utility configuration are presented in figure 49, appendix E and the ESSS only and 4 HMMS configurations in figures 50 and 51, respectively. The position error was essentially the same for both the ESSS and 4 HMMS configurations agreeing within one knot of each other. However, installation of the ESSS system increased the position error from the normal utility configuration by approximately 1.5 knots at lower airspeeds (between 50 and 80 KIAS) and up to 5 knots at higher speeds (120 KIAS). The position error data presented in figure 51 should be incorporated into the applicable ESSS and HELLFIRE missile system operator's manual.

MISCELLANEOUS

33. The ESSS root attachments to the fixed provision mounting points (photo 7, app F) are designed to be covered with a fairing assembly. This evaluation was flown with prototype fairings installed (photo 8) instead of the production fairings (photo 9). When the ESSS was initially installed, the production fairings could not be made to fit because of fastener and hole misalignment of the assembly and mismatched fairing edges projecting beyond the sliding cargo track. At the end of the test program, after 21.1 total flight hours with the ESSS installed, they were again fitted to the aircraft using the existing fastener locations. However, some interference with the cargo door track remained (photo 10). No exact cause for this change in ability to install the production fairings was established. The fit and function of the production fairings should be further evaluated.

CONCLUSIONS

GENERAL

34. Based on this evaluation, the following conclusions were reached regarding the installation of the HELLFIRE missile system on the UH-60A helicopter.

a. Installation of the HELLFIRE Missile System increased the drag of the UH-60A over the ESSS only configuration by 11.0 square feet equivalent flat plate area (para 10).

b. Installation of the ESSS increased the drag of the UH-60A over the normal utility configuration by 10.0 square feet equivalent flat plate area (para 11).

c. The handling qualities of the UH-60A with the HELLFIRE missile system installed were essentially the same as the UH-60A in the normal utility configuration (para 12).

RECOMMENDATIONS

35. The following recommendations are submitted:

a. The UH-60A airspeed system position error data (HELLFIRE missile system installed) should be incorporated into the applicable HELLFIRE missile system operator's manual (para 32).

b. The following CAUTION should be incorporated into the operator's manual (para 13).

CAUTION

> Prior to installation of the HELLFIRE missile system insure that modified input modules (P/N 7035108001-046) have been installed in the aircraft. The increased nose-down pitch attitudes during level flight when the HELLFIRE missile system is installed may result in oil foaming and inadequate lubrication without the required gearbox modification.

c. The fit and function of the production ESSS fairings should be further evaluated (para 33).

APPENDIX A. REFERENCES

1. Letter, AVSCOM, AMSAV-8, 18 December 1986, subject: Preliminary Airworthiness Evaluation (PAE) of the UH-60A/ESSS with the HELLFIRE Launcher Installed.

2. Prime Item Development Specification, Sikorsky Aircraft Division, DARCOM CP-2222-S1000 F, 18 December 1981.

3. Technical Manual, TM 55-1520-237-10, *Operator's Manual, UH-60A Helicopter*, 21 May 1979 with change 42 dated 8 June 1987.

4. Document, Critical Item Development Specification (CIDS) for a UH-60A HELLFIRE System, Document No. SES-700024, dated 20 September 1984.

5. Document, UH-60A HELLFIRE Qualification Program Preliminary Design Review, 5-6 December 1984.

6. Final Report, AEFA Project No. 83-24, *Airworthiness and Flight Characteristics Test of a Sixth Year Production UH-60A*, June 1985.

7. Final Report, AEFA Project No. 82-15, *Airworthiness and Flight Characteristics Test of the UH-60A Configured with the Prototype External Stores Support System*, December 1983.

8. Military Specification, MIL-H-8501A, *Helicopter Flying and Ground Handling Qualities; General Requirements for*, with amendment 1, 3 April 1962.

9. Letter, AVSCOM, AMSAV-E, 3 March 1987, subject: Airworthiness Release for the Conduct of a Preliminary Airworthiness Evaluation of a UH-60A/ESSS Configured with the HELLFIRE Launcher Installed.

10. Test Plan, AEFA Project No. 86-25, *Preliminary Airworthiness Evaluation of the UH-60A Equipped with the HELLFIRE Launcher Installed*, January 1987.

11. Final Report, AEFA Project No. 86-10, *Preliminary Airworthiness Evaluation of the UH-60A Equipped with the XM-139 VOLCANO Dispensing System*, August 1987.

12. DoD Flight Information Publication, *Flight Information Handbook*, Defense Mapping Agency Aerospace Center, 18 December 1986.

13. Engineering Design Handbook, Army Material Command, AMC Pamphlet 706-204, *Helicopter Performance Testing*, 1 August 1974.

14. Flight Test Manual, Naval Air Test Center FTM No. 101, *Stability and Control*, 10 June 1968.

APPENDIX B. DESCRIPTION

GENERAL

1. The UH-60A Black Hawk, is a twin turbine engine, single main rotor helicopter with nonretractable wheel-type landing gear. A movable horizontal stabilator is located on the lower portion of the tail rotor pylon. The main and tail rotor are both four-bladed with a capability of manual main rotor blade and tail pylon folding. The cross-beam tail rotor with composite blades is attached to the right side of the pylon. The tail rotor shaft is canted 20° upward from the horizontal. Primary mission gross weight is 16,260 pounds and maximum alternate gross weight is 20,250 pounds. The UH-60A is powered by two General Electric T700-GE-700 turboshaft engines each having an installed thermodynamic rating (30 minute) of 1553 shaft horsepower (shp) (power turbine speed of 20,900 revolutions per minute) at sea level, standard-day static conditions. Installed dual-engine power is transmission limited to 2828 shp. The aircraft also has an automatic flight control system and a command instrument system. The test helicopter, UH-60A U.S. Army S/N 84-23953, was manufactured by Sikorsky Aircraft Division of United Technologies Corporation and is a production Black Hawk equipped with fixed provision mounting points. The main differences between the test aircraft and a UH-60A in the normal utility configuration are the addition of the HELLFIRE missile system and an external nose-mounted airspeed boom and the associated special test instrumentation. Photos 1 through 4, appendix F, show views of the test aircraft with the HELLFIRE Missile System installed. A more complete description of the UH-60A helicopter in the normal utility configuration can be found in reference 2, appendix A.

EXTERNAL STORES SUPPORT SYSTEM

2. The production External Stores Support System (ESSS) consists of the airframe fixed provisions and the removable external stores subsystem. The ESSS was designed to enable the UH-60A to carry external stores such as auxiliary fuel tanks or various weapon systems, such as the HELLFIRE missile system.

3. The airframe fixed provisions (photos 5 through 7) are the fuselage attachment structure required for the installation of the removable external stores subsystem. The removable external stores subsystem consists of the horizontal store support which is a composite boxed I-beam structure, the support struts (two on each wing) and the vertical stores pylons (two on each wing) all of which are enclosed with thin aluminum fairings. The fairings at the wing root flown in this evaluation were prototype models (photo 8). Since the production versions (photo 9) could

not be fitted onto the aircraft initially. When the production fairings were installed at the conclusion of the test program, some interference with the sliding cargo door seals remained (photo 10). BRU-22A ejector racks were mounted on the vertical stores pylons at a 1° nose-up angle with reference to the aircraft waterline. The ESSS is shown installed in photo 11.

HELLFIRE MISSILE SYSTEM

4. The HELLFIRE missile is an air or ground launched anti-armor weapon which homes on a laser designation provided by an external ground or airborne source. The HELLFIRE system, as designed for the UH-60A, does not include target acquisition or designation capability. The primary mission of the UH-60A HELLFIRE missile system is to provide the Corps Commander with the flexibility to reinforce the Corps attack helicopter assets in order to meet emergency surge requirements. The secondary mission is to serve as a resupply platform, delivering the missiles to the primary attack helicopters.

5. The UH-60A HELLFIRE missile system incorporates a UH-60A aircraft configured with the ESSS, the UH-60A HELLFIRE system, and the HELLFIRE Modular Missile System (HMMS). The HELLFIRE missile system is designed to be easily and rapidly installed and removed from the aircraft.

6. The UH-60A HELLFIRE system consists of the aircraft fixed provisions, support equipment, and the UH-60A HELLFIRE Missile Equipment (UH-60A HME). The UH-60A HME was not installed for this test, but a brief description is included here. The UH-60A HME is a kit consisting of a Control Display Unit (CDU), Remote HELLFIRE Electronics (RHE), two Pilot Steering Indicators (PSI), a master arm panel, two firing switches, required electrical harnesses, and the associated installation hardware. The CDU provides cockpit control functions for the HELLFIRE system by displaying system status, missile inventory, and indicating selected modes and missile activation. The RHE provides all control and management funtions of the UH-60A HME and is palletized for mounting in the aft cabin area along with the Automatic Target Hand-Off System (ATHS). The ATHS provides the capability of rapidly receiving automatic target information for the HELLFIRE missile system. Two PSI's are mounted on top of the glareshield in front of the pilot and copilot to provide graphic "steer to" information in order to meet azimuth and elevation launch constraints.

7. The HMMS consists of four AGM-114A HELLFIRE missiles weighing approximately 98 pounds each and an M272 launcher assembly weighing approximately 142 pounds. Each launcher is designed to be mounted on a UH-60A ESSS pylon. The ESSS can accommodate up to four HMMS (two on each side) for a total capacity of 16 HELLFIRE missiles. Inert HELLFIRE missiles were used to simulate actual missile weight and drag characteristics during this test, and are shown installed in photos 12 through 14. The ESSS stores jettison system was fully operational, and the interface control panel is shown in photo 15.

MODIFICATIONS

8. Several modifications were made to the test aircraft to accommodate ballast, instrumentation, or for safety purposes. These modifications were not part of the HELLFIRE Missile System or a UH-60A in the normal utility configuration. Mounting provisions to accomodate ballast are shown in photos 16 and 17. An instrumentation package was installed in the cargo compartment and can be seen in photo 18. Sikorsky drag estimates for the external items (photos 19 through 23) totalled 3.04 square feet of equivalent flat plate area. Each item is listed below:

ITEM

Standard size tail rotor slip ring
Medium size main rotor slip ring with cover
Nose boom
Tail-mounted TM antennas (2)
Belly-mounted TM antenna
Main rotor instrumentation
Ambient air temperature sensor
Emergency crew door handles (2)

APPENDIX C. INSTRUMENTATION

GENERAL

1. The test instrumentation was installed, calibrated and maintained by Sikorsky Aircraft personnel. A test boom, with a swiveling pitot-static tube and angle-of-attack and sideslip vanes, was installed at the nose of the aircraft (photo 19, app F). Slip ring assemblies were installed on the main and tail rotor shafts (photos 20 and 21). Three telemetry antennas were installed. Two were mounted to the top left side of the tail boom and one was mounted on the belly of the aircraft just forward of the tail boom (photo 22). All other instrumentation was installed inside the test aircraft. Data were obtained from calibrated instrumentation and displayed or recorded as indicated below.

Pilot Panel

Airspeed (boom)
Altitude (boom)
Rate of climb (boom)
Rotor speed
Engine torque* **
Turbine gas temperature* **
Power turbine speed (Np)* **
Gas producer speed (Ng)* **
Control positions
    Longitudinal
    Lateral
    Directional
    Collective
Horizontal stabilator position
Angle of sideslip

Copilot Panel

Airspeed*
Altitude*
Rotor speed*
Engine torque* **
Fuel remaining* **
Total air temperature
Instrumentation controls
Run number
Event switch

*Ship's system
** Both engines

2. Parameters recorded on board the aircraft in pulse code modulation format and available for telemetry include the following:

Airspeed (boom)
Altitude (boom)
Airspeed (ship's)
Altitude (ship's)
Radar altimeter (low range)
Total air temperature
Rotor speed
Gas generator speed**
Power turbine speed**
Engine fuel flow**
Engine fuel temperature**
Engine output shaft torque**
Turbine gas temperature**
Longitudinal acceleration at the cg
Lateral acceleration at the cg
Normal acceleration at the cg
Stabilator position
Control positions
- Longitudinal
- Lateral
- Directional
- Collective

Aircraft Attitude
- Pitch
- Roll

Heading
Angular Acceleration
- Pitch
- Roll
- Yaw

SAS output position
- Longitudinal
- Lateral
- Directional

Main rotor shaft torque
Tail rotor shaft torque
Tail rotor impressed pitch (blade angle at 0.75 blade span)
Angle of sideslip
Angle of attack
Time of day
Run number
Pilot event switch

**Both engines

3. Vibration was measured in the following locations and directions and recorded in frequency modulation format onboard the aircraft:

Vertical pilot seat
Lateral pilot seat
Longitudinal pilot seat
Lateral copilot seat
Vertical pilot floor
Lateral pilot floor
Longitudinal pilot floor
Vertical copilot floor
Vertical pilot instrument panel
Vertical copilot instrument panel
Center of gravity vertical
Center of gravity lateral
Center of gravity longitudinal
Vertical tail rotor gearbox
Lateral tail rotor gearbox
Longitudinal tail rotor gearbox

TEST BOOM AIRSPEED SYSTEM

4. The test boom airspeed system mounted at the nose of the test aircraft provided measurements of airspeed and altitude. Sensors for angles of attack and sideslip were also mounted on the test boom (photo 19, app F). The tip of the swiveling pitot-static tube was at fuselage station 97, 79.6 inches forward of the nose of the aircraft, 25.7 inches to the right of the aircraft reference buttline, and at waterline 208, 7 inches below the forward avionics bay floor.

5. The test boom airspeed system along with the ship's standard systems were calibrated in level flight (ESSS only and HELLFIRE missile system configuration) using a calibrated trailing bomb to determine the position error. The position error of the ship's airspeed system and the boom airspeed system is presented in figures 1 and 2.

ENGINE CALIBRATION

6. Calibrations of the engine torque sensor systems were conducted by the engine manufacturer, General Electric. Figures 3 and 4 present the calibrations used to determine engine power.

SPECIAL EQUIPMENT

Weather Station

7. A portable weather station consisting of an anemometer, sensitive temperature gauge, relative humidity sensor and barometer, was used to record wind speed, wind direction, ambient temperature and humidity and pressure altitude at 50 feet above ground level during the low airspeed handling qualities tests.

Ground Pace Vehicle

8. Pace vehicle speedometers were calibrated by Sikorsky personnel. The pace vehicles were used to establish precise ground speed during the low airspeed handling qualities tests.

FIGURE 1
BOOM AIRSPEED CALIBRATION
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	TEST METHOD
17040	350.2	0.2 RT	6460	15.0	TRAILING BOMB

NOTES:
1. ESSS ONLY CONFIGURATION
2. LEVEL FLIGHT
3. BALL CENTERED TRIM CONDITION
4. MAIN ROTOR SPEED=258 RPM

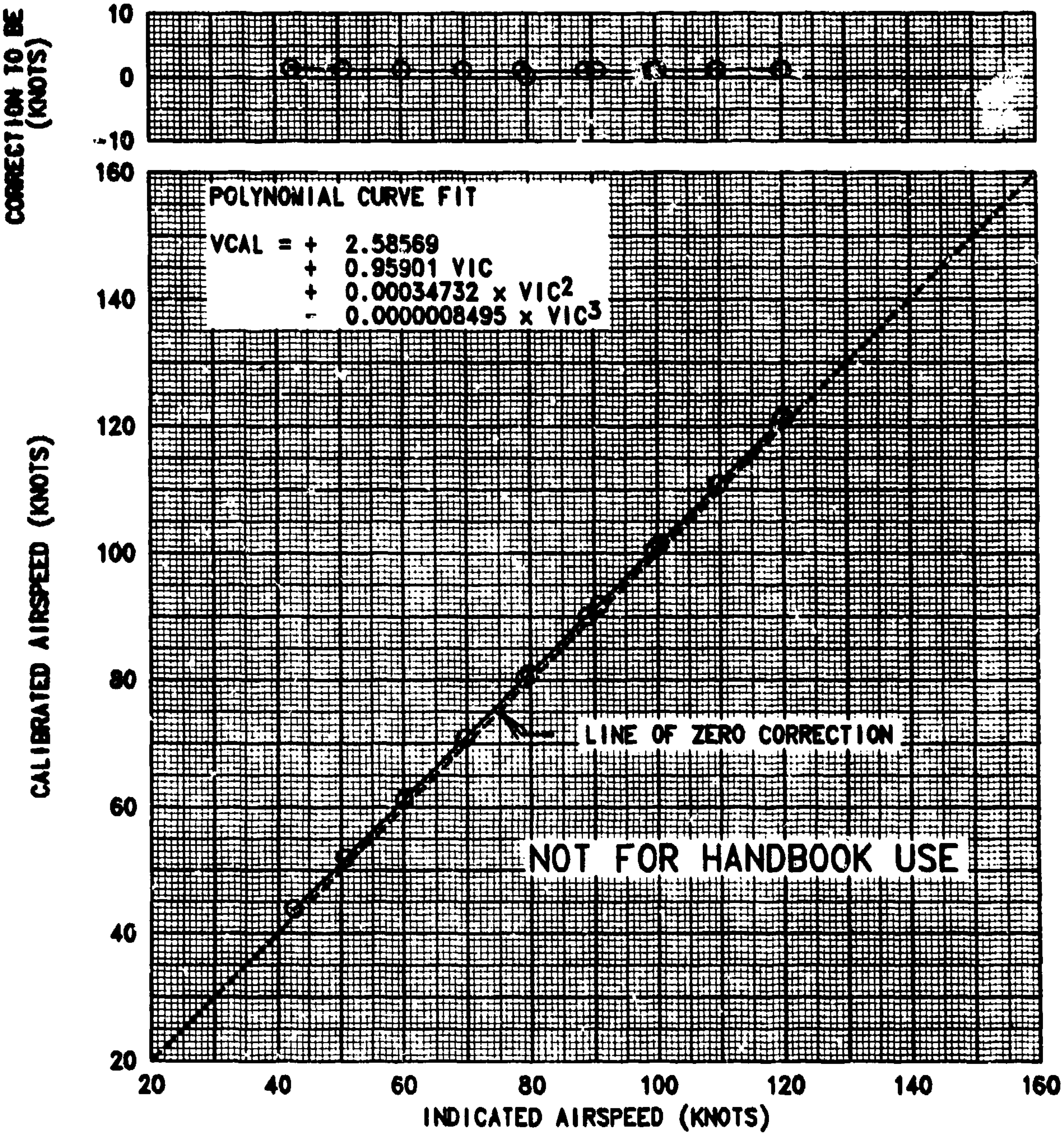


FIGURE 2
BOOM AIRSPEED CALIBRATION
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	TEST METHOD
16880	349.7	0.2 RT	5090	13.0	TRAILING BOMB

NOTES: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. BALL CENTERED TRIM CONDITION
4. MAIN ROTOR SPEED=258 RPM

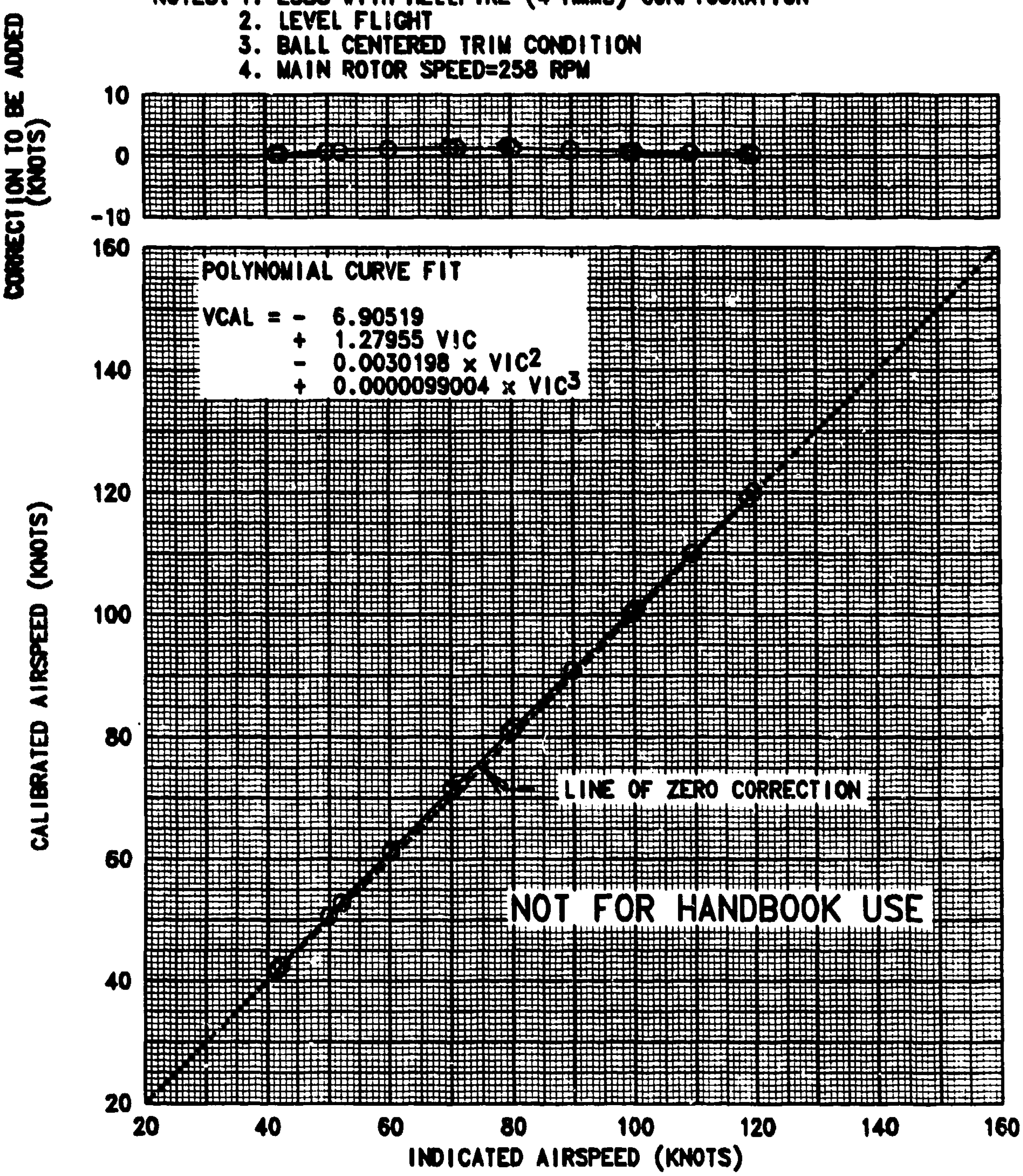


FIGURE 3

ENGINE TORQUEMETER CALIBRATION

UH-60A USA S/N 84-23953

T700-GE-700 S/N 306625

NOTES: 1. NUMBER ONE ENGINE

2. POWER TURBINE SPEED = 20,900 RPM

3. DATA OBTAINED FROM G E ENGINE PRODUCTION RATING SHEET

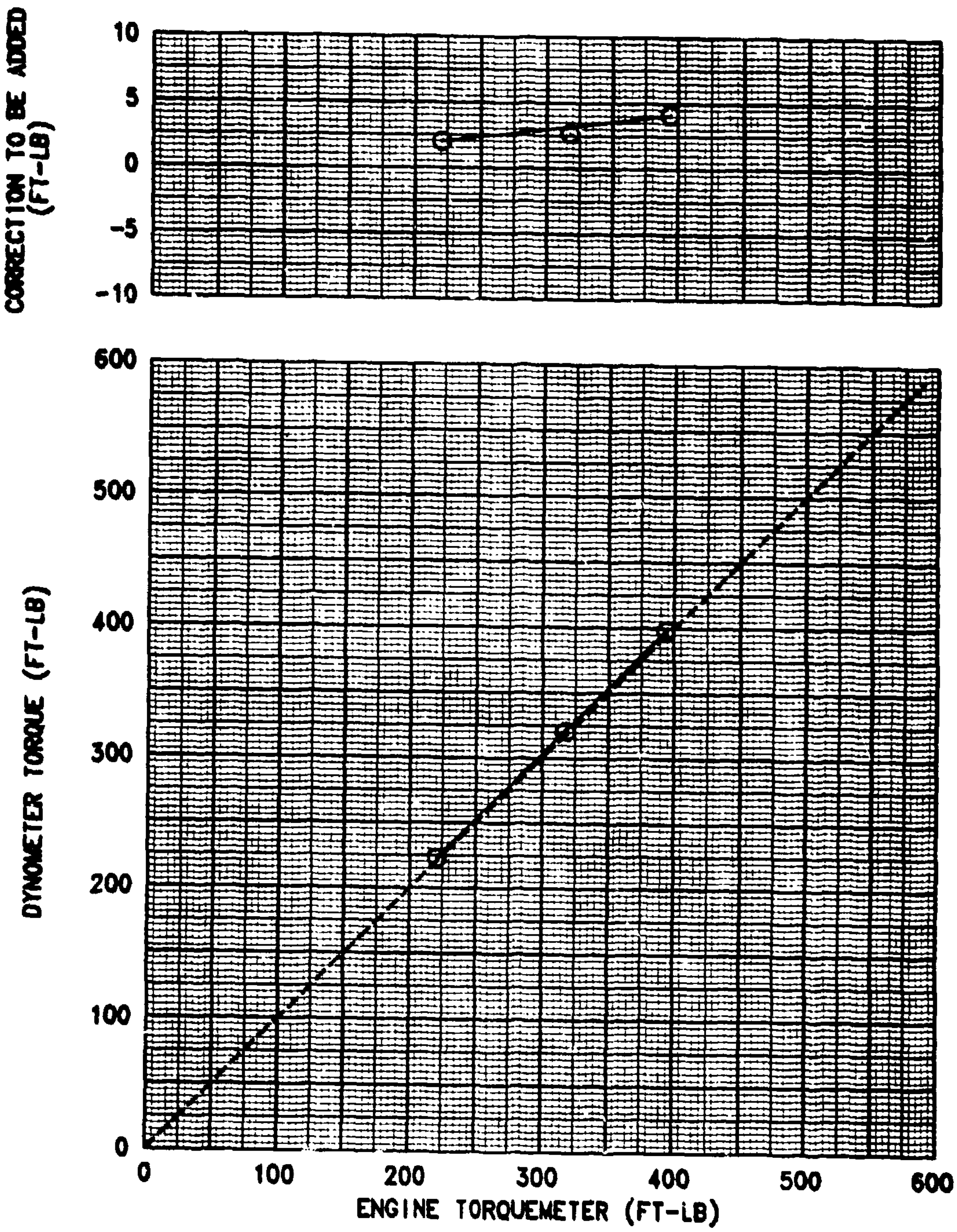
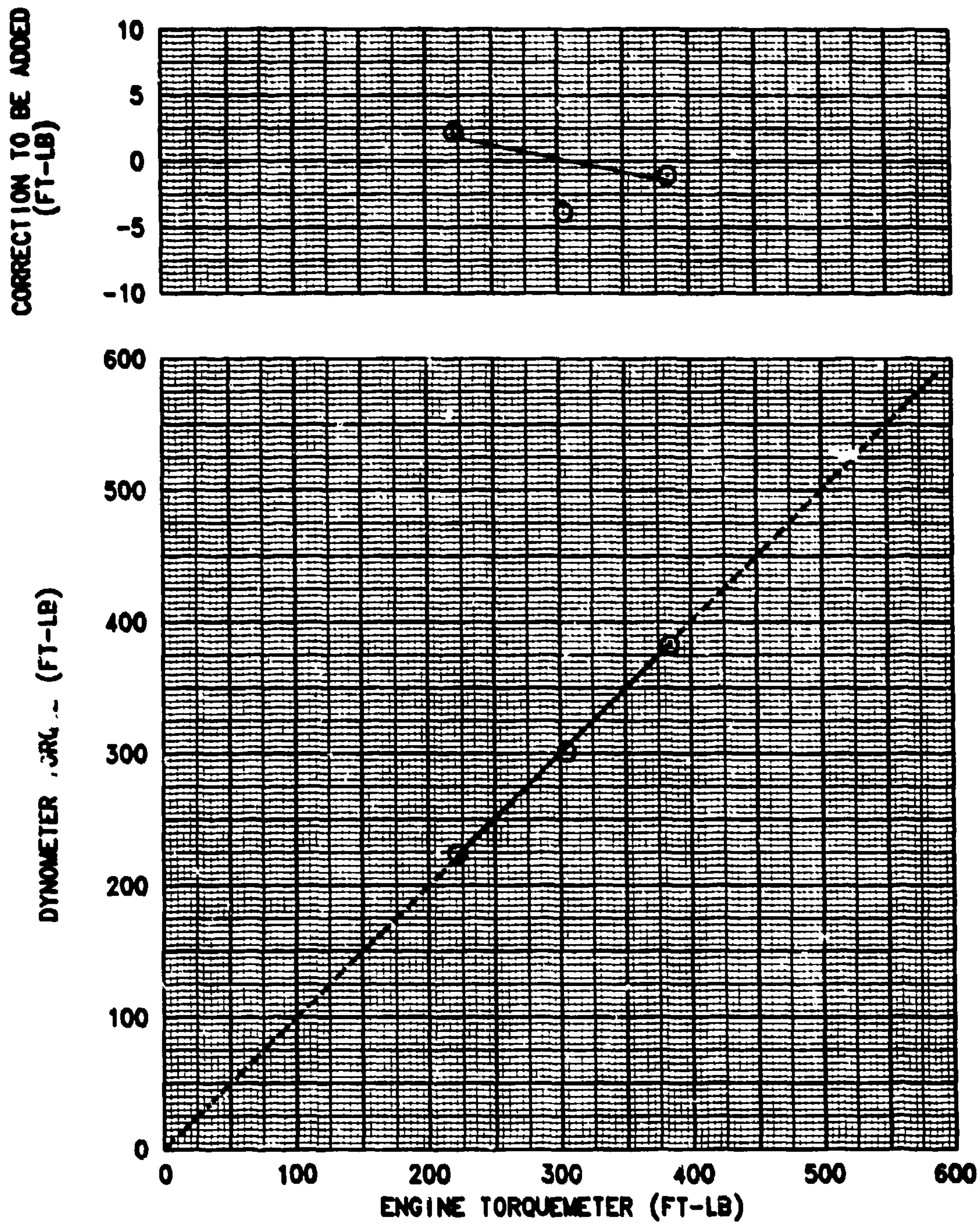


FIGURE 4
ENGINE TORQUEMETER CALIBRATION
UH-60A USA S/N 84-23953
T700-GE-700 S/N 306262

NOTES: 1. NUMBER TWO ENGINE
2. POWER TURBINE SPEED = 20,900 RPM
3. DATA OBTAINED FROM G E ENGINE PRODUCTION RATING SHEET



APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

AIRCRAFT RIGGING

1. Prior to the start of testing, a flight controls engineering rigging check was performed on the main and tail rotors by Sikorsky Aircraft and monitored by the U.S. Army Aviation Engineering Flight Activity. The stabilator control system was also checked to ensure compliance with the production stabilator schedule. The rigging data are presented in table 1.

AIRCRAFT WEIGHT AND BALANCE

2. The test aircraft was weighed in both the ESSS only configuration and with the HELLFIRE missile system installed, with full oil and all fuel drained, all ballast removed, and test instrumentation system and ballast mounting provisions installed. The initial weight of the aircraft in the ESSS only configuration was 13,096 lb with a longitudinal center of gravity (cg) located at fuselage station 357.8 and a mid lateral cg, and in the HELLFIRE missile configuration was 15,176 lb with a longitudinal cg at FS 351.9. Installation of the HELLFIRE missile system increased the empty weight of the aircraft by 2080 lb. The fuel weight for each performance test flight was determined by pre- and post-flight aircraft weighings and fuel flowmeter instrumentation.

PERFORMANCE

General

3. Performance data were obtained using the basic methods described in Army Material Command Pamphlet AMCP 706-204 (ref 13, app A). Level flight performance and control positions in level flight were obtained in coordinated (ball-centered) flight. Referred rotor speed was maintained constant for all performance tests at 258 rpm. Longitudinal center of gravity (cg) was allowed to vary ± 1.5 inch during each test flight, but for each data set (consisting of several flights in the same aircraft configuration at different thrust coefficient values) the average cg location was maintained constant near the proposed mission value. The data were analyzed to determine the power required difference between the UH-60A in the ESSS only configuration and the UH-60A configured with the HELLFIRE missile system in terms of change in equivalent flat plate area (ΔF_e).

4. Helicopter performance was generalized through the use of non-dimensional coefficients as follows using the 1968 U.S. Standard Atmosphere:

Table 1. Main and Tail Rotor Rigging Information

Main Rotor Rigging

Flight Control Position				Blade Angle[1] (deg)				Flight Control Position (deg)		
Long	Lat	Coll	Pedal	0	90	180	270	Long Cont[2]	Lat Cont[3]	Coll Cont[4]
Aft	*[5]	*	*		20.0		-4.0	-12.0		
Block[6]	*	*	*		11.1		5.5	- 2.8		
Block	*	High	*	20.0	16.2	11.4	15.0	- 0.6	-4.3	15.7
Block	*	Low	*	2.6	5.3	-1.9	-5.7	- 5.5	-2.3	0.1
Aft	*	High	*		26.8		4.8	-11.0		
Fwd	Left	Low	*	7.7	-12.0	-8.1	11.0	11.5	-7.9	-0.4
Block	*	*	Right		6.7		9.6	1.5		
Block	*	*	Left		15.2		0.3	- 7.5		
Fwd	*	*	Right		-10.0		25.4	17.7		
Aft	Left	*	Left	15.8	19.6	0.8	-4.5	-12.1	-8.3	7.5
Fwd	Right	*	Left	2.0	-5.2	13.9	20.4	12.8	6.0	7.8
Aft	*	High	Left		26.8		4.3	-11.3		
Fwd	*	High	Right		-1.4		32.2	16.8		
Fwd	Right	High	Left	9.9	-1.6	20.9	32.0	16.8	5.5	15.3
Aft	Left	High	Right	24.0	22.9	8.2	9.1	-6.9	-7.9	16.1
Aft	Right	Low	Right	-6.9	9.8	7.4	-9.9	-9.9	7.2	0.1
Aft	Left	Low	Left	6.9	8.9	-8.5	-10.3	-9.6	-7.7	-0.8

Tail Rotor Rigging

Flight Control Position		Blade Angle (deg)[7]
Collective	Pedal	
*	Left	15.7
*	Right	-15.4
*	*	0.5
Low	*	-7.3
High	Left	16.5
High	Right	-5.6
Low	Right	-15.7
Low	Left	8.2

NOTES:

[1]Measured on the Black Blade at the cuff.
[2]270° reading minus 90° reading divided by 2.
[3]180° reading mimus 0° reading divided by 2.
[4]Sum of all four readings divided by 4.
[5]* Indicates appropriate control was pinned at a rigged position.
[6]Indicates a block was inserted between the aft longitudinal control stop and the cyclic control such that no limiters are contacted to determine longitudinal to collective coupling.
[7]Measured on the Blue Blade at the cuff.

a. Coefficient of Power (C_P):

$$C_P = \frac{SHP\ (550)}{\rho A(\Omega R)^3} \qquad (1)$$

b. Coefficient of Thrust (C_T):

$$C_T = \frac{GW}{\rho A(\Omega R)^2} \qquad (2)$$

c. Advance Ratio (μ):

$$\mu = \frac{V_T(1.6878)}{\Omega R} \qquad (3)$$

Where:

SHP = Engine output shaft horsepower (both)
ρ = Ambient aft density ($lb\text{-}sec^2/ft^4$)
A = Main rotor disc area = 2262.03 ft^2
Ω = Main rotor angular velocity (radians/sec)
R = Main rotor radius = 26.833 ft
GW = Gross weight (lb)

$$V_T = \text{True airspeed (kt)} = \frac{V_E}{1.6878\sqrt{\rho/\rho_0}}$$

1.6878 = Conversion factor (ft/sec-kt)
ρ_0 = 0.0023769 ($lb\text{-}sec^2/ft^4$)

5. The engine output shaft torque was determined by use of engine torque sensors. The power turbine shaft contains a torque sensor tube that mechanically displays the total twist of the shaft. A concentric reference shaft is secured by a pin at the front end of the power turbine drive shaft and is free to rotate relative to the power turbine shaft at the rear end. The relative rotation is due to transmitted torque, and the resulting phase angle between the reference teeth on the two shafts is picked up by the torque sensor. This torque sensor was calibrated in a test cell by the engine manufacturer. The output from the engine

torque sensor was recorded by the on-board data recording system. The output SHP was determined from the engine's output shaft torque and rotational speed by the following equation:

$$SHP = \frac{2\pi Q(Np)}{33{,}000} \qquad (4)$$

Where:

Q = Engine output shaft torque (ft-lb)
Np = Engine output shaft rotational speed (rpm)

Level Flight Performance

6. Each speed power data set was flown in ball-centered flight by reference to the ship's turn and slip indicators at a predetermined thrust coefficient (C_T) and referred rotor speed ($N_R/\sqrt{\theta}$). Both the pilot's and copilot's turn and slip indicators were checked for alignment with the aircraft positioned in a level attitude on the ground. To maintain the ratio of gross weight to pressure ratio (W/δ) constant, altitude was increased as fuel was consumed. To maintain $N_R/\sqrt{\theta}$ constant, rotor speed was varied as appropriate for the ambient air temperature. Corrections to power required were made for the installation of test instrumentation. The power consumption for the electrical operation of the instrumentation equipment was measured and determined to be 0.76 shaft horsepower (shp) and subtracted from the power required data. The effects of the external instrumentation and nonstandard aircraft equipment were estimated by the contractor to be the equivalent of 3.04 square feet of equivalent flat plate area.

7. The nondimensional coefficients (equations 1 through 3) can be expressed in terms of referred rotor speed as follows:

$$C_P = \frac{SHP\ (478935.3)}{\delta\sqrt{\theta}\left(\dfrac{N_R}{\sqrt{\theta}}\right)^3 (\rho_0 A R^3)} \qquad (5)$$

$$C_T = \frac{GW\ (91.19)}{\delta \left(\frac{N_R}{\sqrt{\theta}}\right)^2 (\rho_0 A R^2)} \tag{6}$$

$$\mu = \frac{V_T\ (16.12)}{(R\sqrt{\theta}) \left(\frac{N_R}{\sqrt{\theta}}\right)} \tag{7}$$

Test-day level flight data were corrected to standard day conditions by the following equations:

$$SHP_s = SHP_t \left(\frac{P_s}{P_t}\right) \left(\frac{N_{R_s}}{N_{R_t}}\right)^3 \tag{8}$$

$$V_{T_s} = V_{T_t} \left(\frac{N_{R_s}}{N_{R_t}}\right) \tag{9}$$

Where:

Subscript t = Test day
Subscript s = Standard day

$$\delta = \text{Pressure ratio} = 1 - \left(\frac{H_p}{145442.15}\right)^{5.255863}$$

$$\theta = \text{Temperature ratio} = \frac{T_A + 273.15}{288.15}$$

T_A = Ambient air temperature (°C)
N_R = Main rotor speed (rev/min)
478935.3 = Conversion factor (ft-lb-sec^2-rev^3/min^3-SHP)
91.19 = Conversion factor (sec^2-rev^2/min^2)

$\rho = \rho_0 \times \sigma$
$\sigma = \rho / \rho$
16.12 = Conversion factor (ft-rev/min-kt)

Test data corrected for instrumentation electrical power consumption and corrected to standard altitude and ambient temperature are presented in figures 3 through 10, appendix E.

8. The data obtained in the ESSS only configuration were analyzed by use of a simulated three dimensional plot (C_T and μ versus C_P). The reduction of this simulated three dimensional plot to a family of curves of C_T versus Cp, for a constant μ value, allows determination of the power required as a function of airspeed for any value of C_T. The data obtained in both aircraft configurations were compared to determine change in the equivalent flat plate area using the following equation.

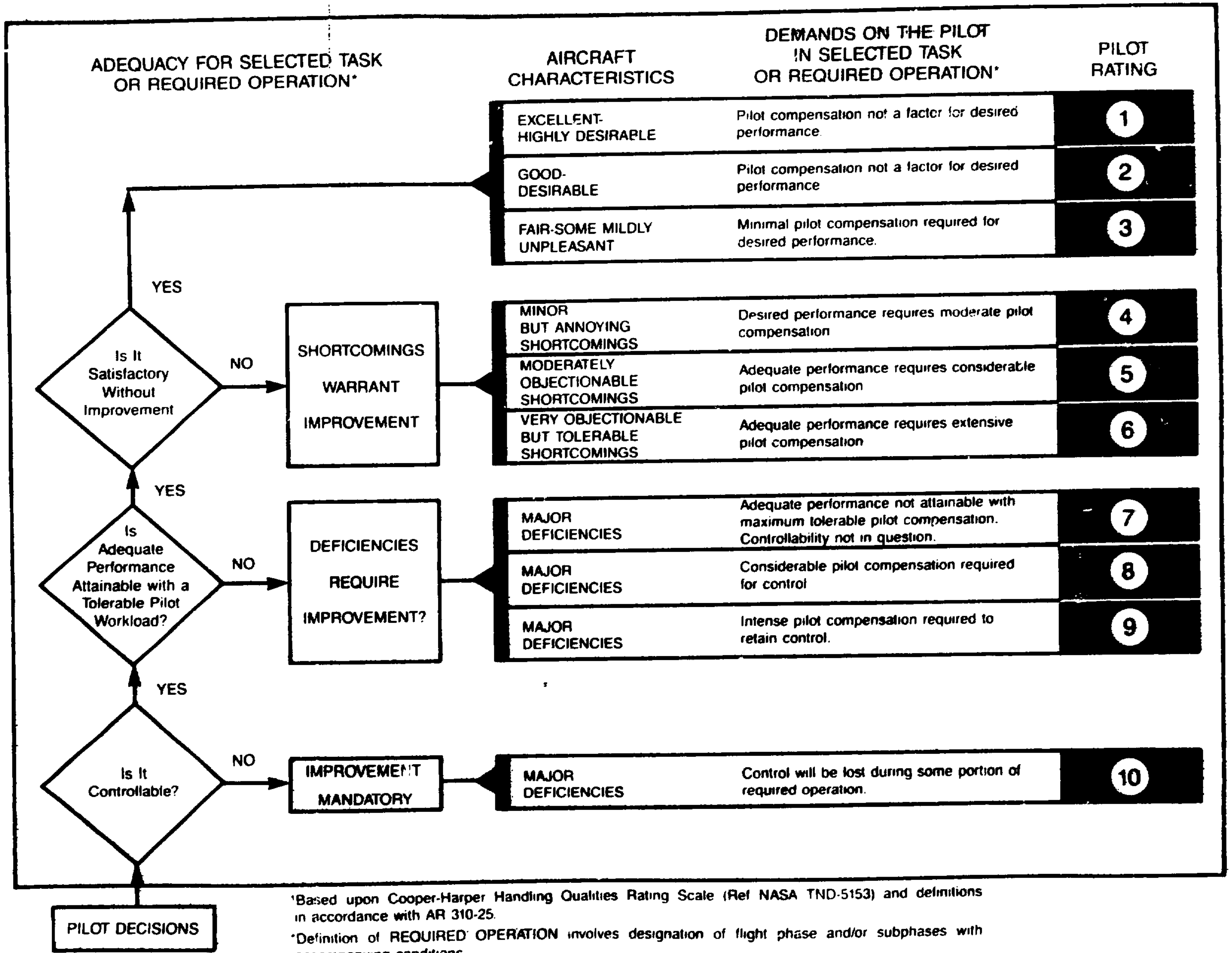
$$\Delta F_e = \frac{\Delta C_p(2A)}{\mu^3} \quad (10)$$

Where:

ΔF_e = Change in equivalent flat plate area (ft^2)

HANDLING QUALITIES

9. Handling qualities data were evaluated using standard test methods described in Naval Air Test Center Flight Test Manual, FTM No. 101 (ref 14). A Handling Qualities Rating Scale (HQRS) (fig. 1) was used to augment pilot comments regarding aircraft handling qualities.



*Based upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TND-5153) and definitions in accordance with AR 310-25.

*Definition of REQUIRED OPERATION involves designation of flight phase and/or subphases with accompanying conditions.

Figure 1. Handling Qualities Rating Scale

APPENDIX E. TEST DATA

INDEX

FIGURE 1
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

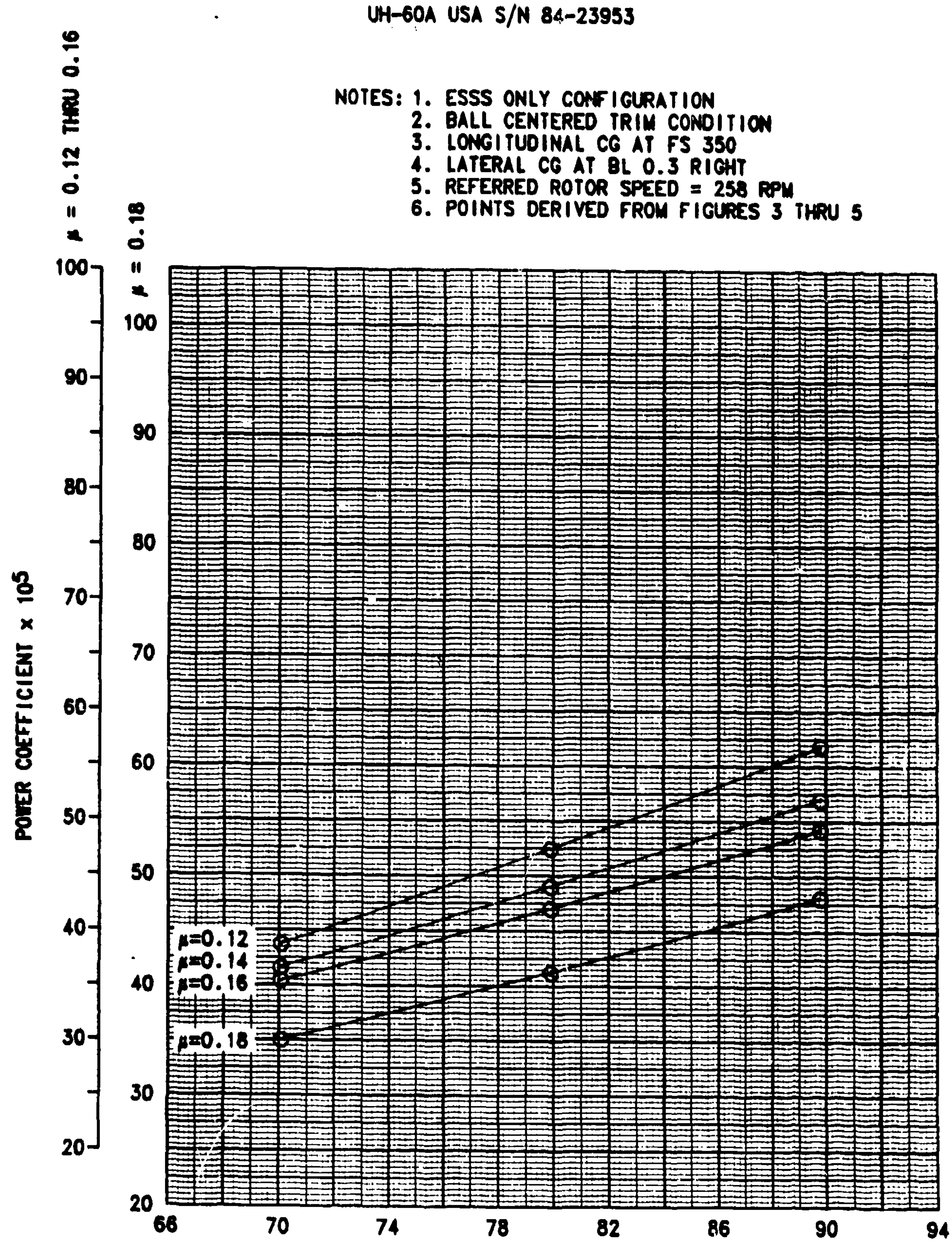


FIGURE 2
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

NOTES: 1. ESSS ONLY CONFIGURATION
2. BALL CENTERED TRIM CONDITION
3. LONGITUDINAL CG AT FS 350
4. LATERAL CG AT BL 0.3 RIGHT
5. REFERRED ROTOR SPEED = 258 RPM
6. POINTS DERIVED FROM FIGURES 3 THRU 5

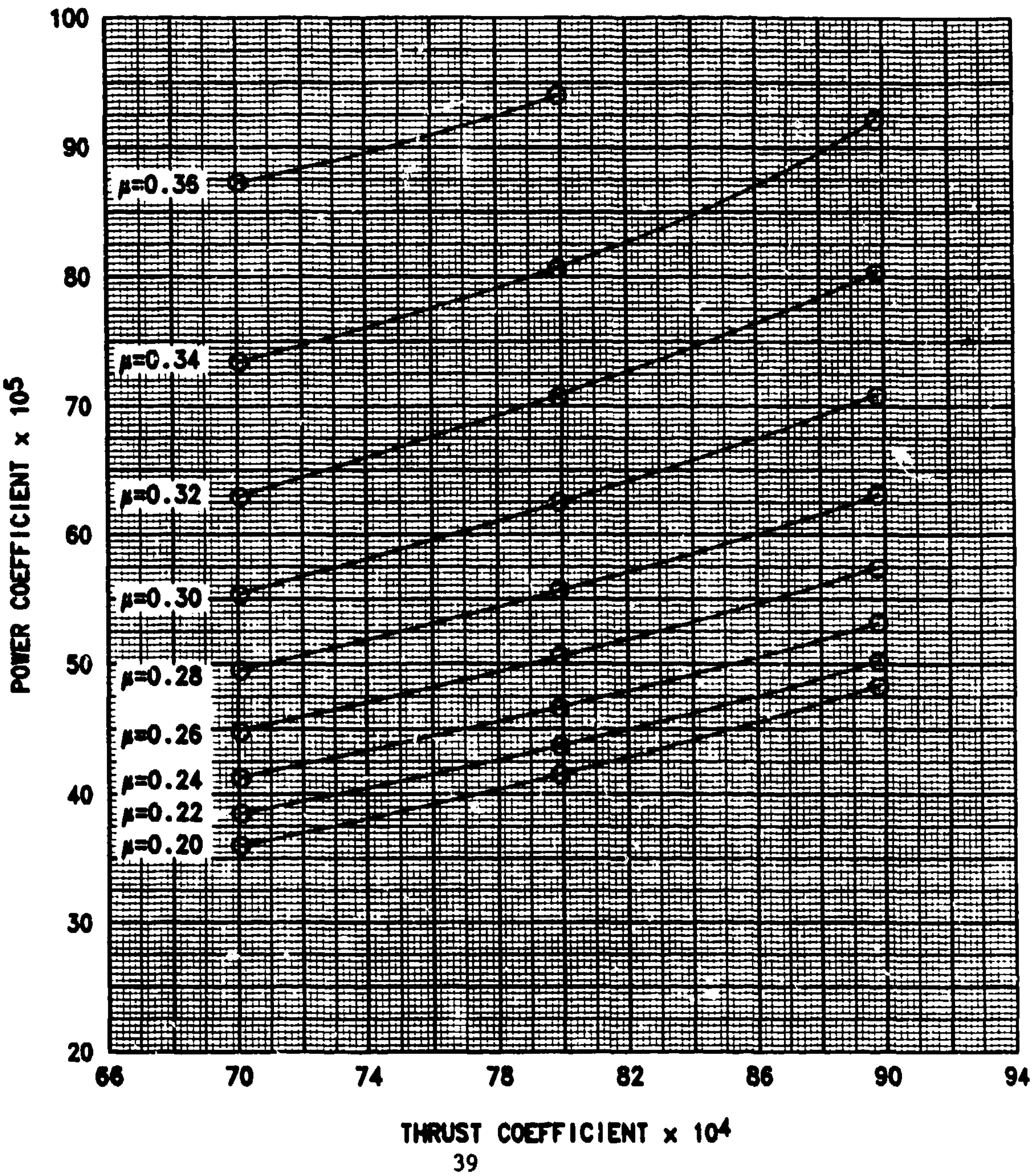


FIGURE 3

LEVEL FLIGHT PERFORMANCE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG COEFFICIENT OF THRUST
17015	350.1	0.3 RT	5290	17.4	257.7	0.007006

NOTES:
1. ESSS ONLY CONFIGURATION
2. BALL CENTERED TRIM CONDITION

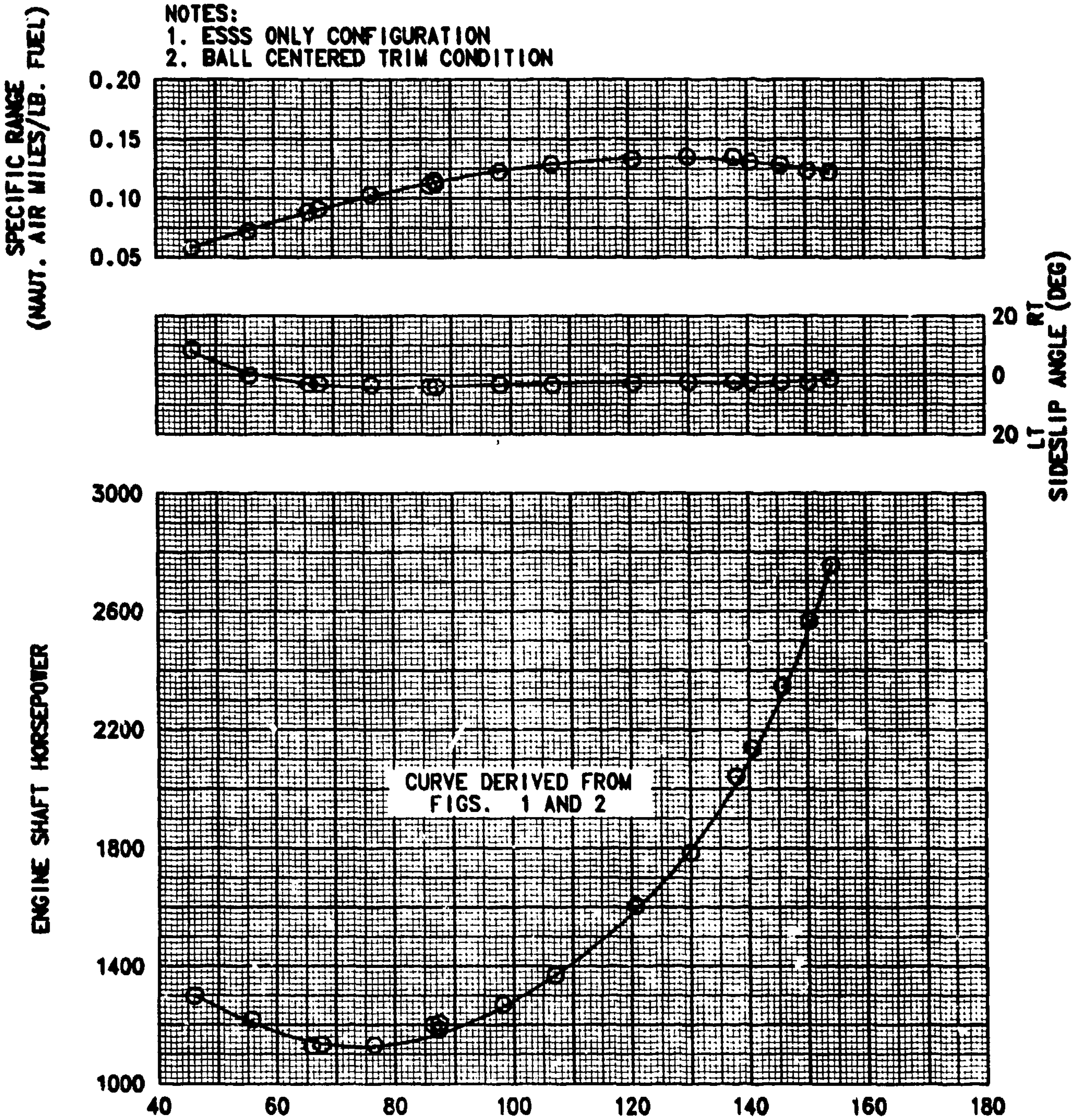


FIGURE 4
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG COEFFICIENT OF THRUST
16810	349.2	0.3 RT	9330	11.5	257.9	0.007991

NOTES:
1. ESSS ONLY CONFIGURATION
2. BALL CENTERED TRIM CONDITION

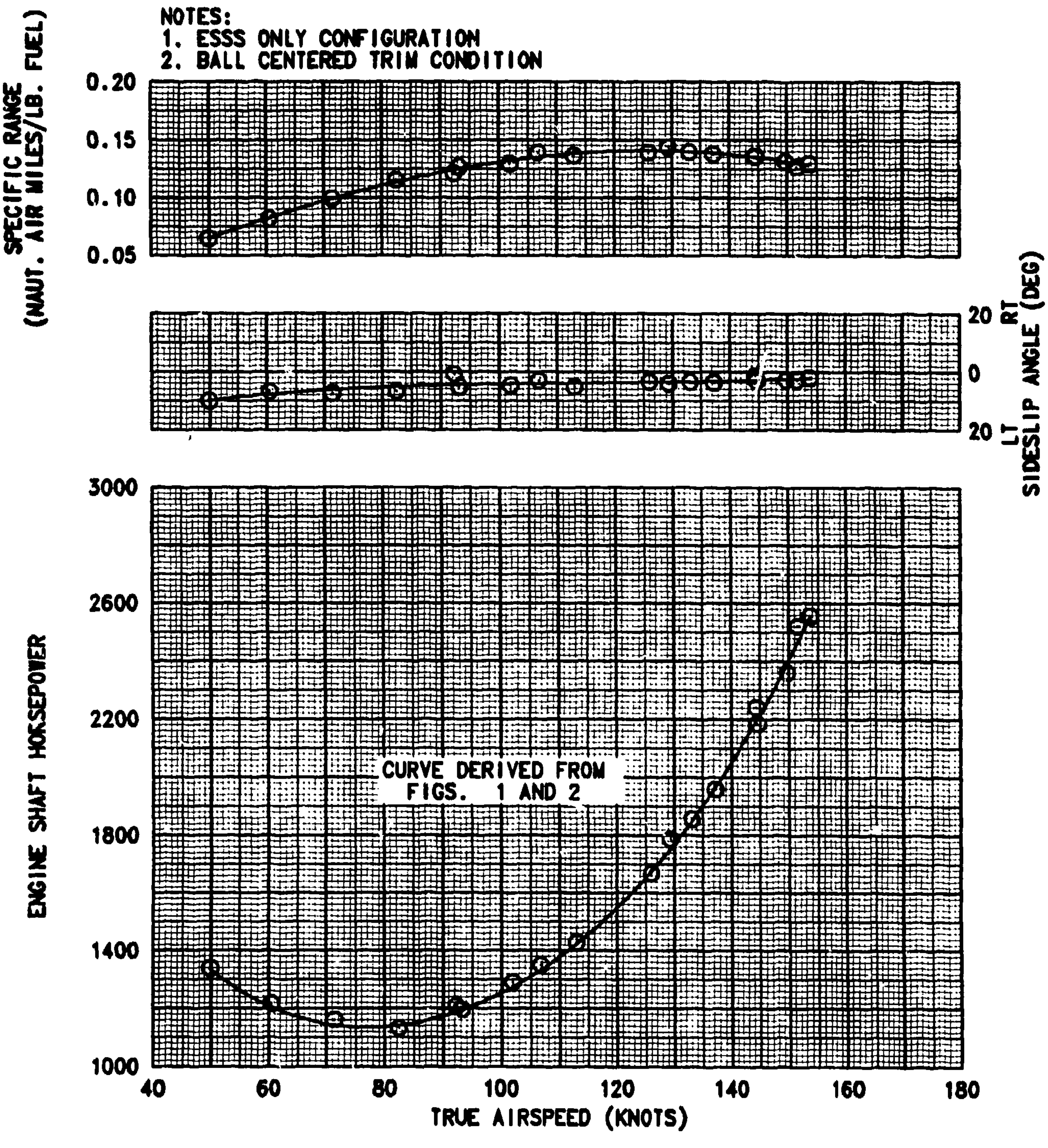


FIGURE 5

LEVEL FLIGHT PERFORMANCE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG COEFFICIENT OF THRUST
16880	349.5	0.3 RT	12350	6.0	258.1	0.008978

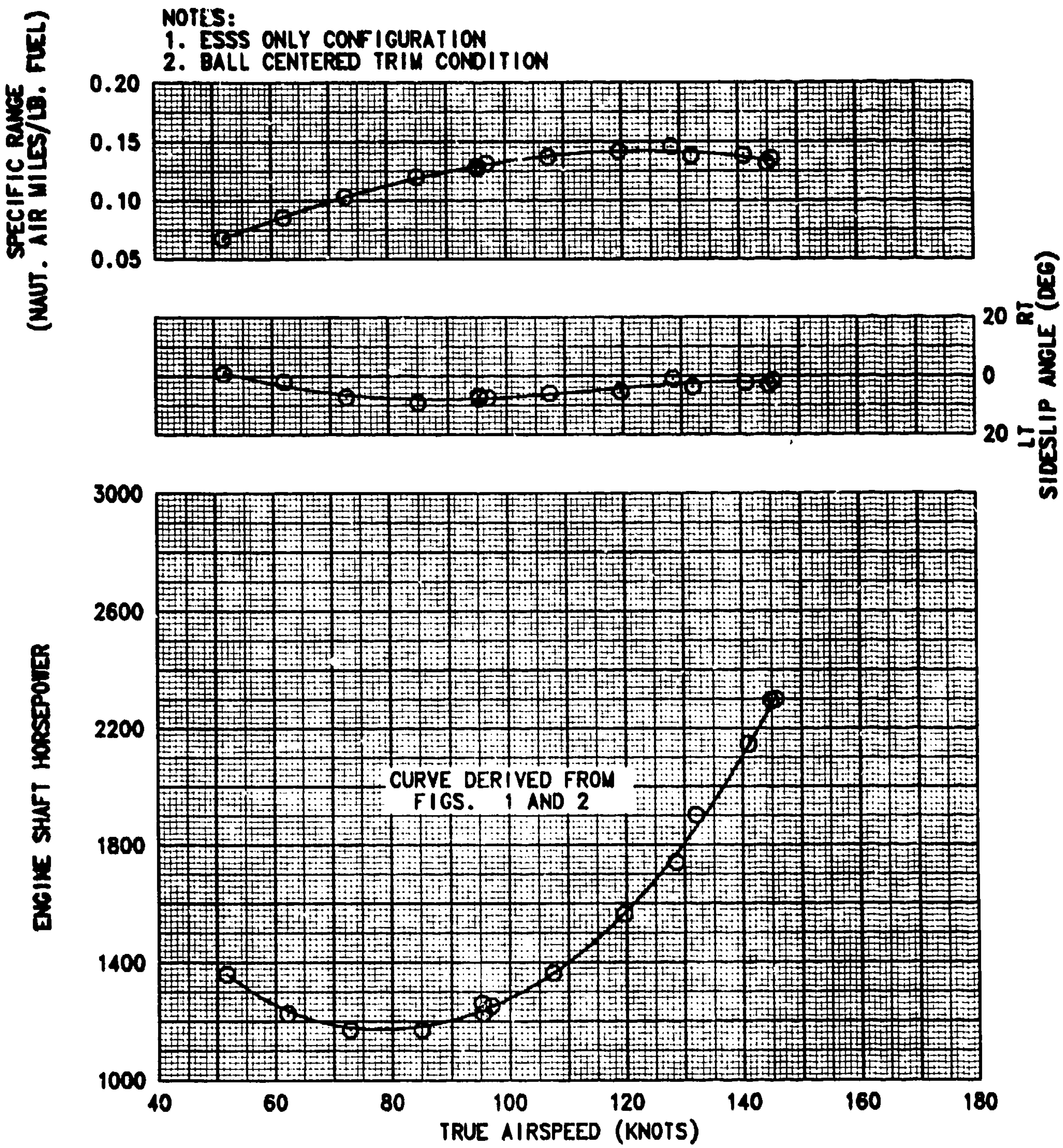


FIGURE 6

LEVEL FLIGHT PERFORMANCE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG COEFFICIENT OF THRUST
16950	350.0	0.3 RT	5250	16.0	258.0	0.006991

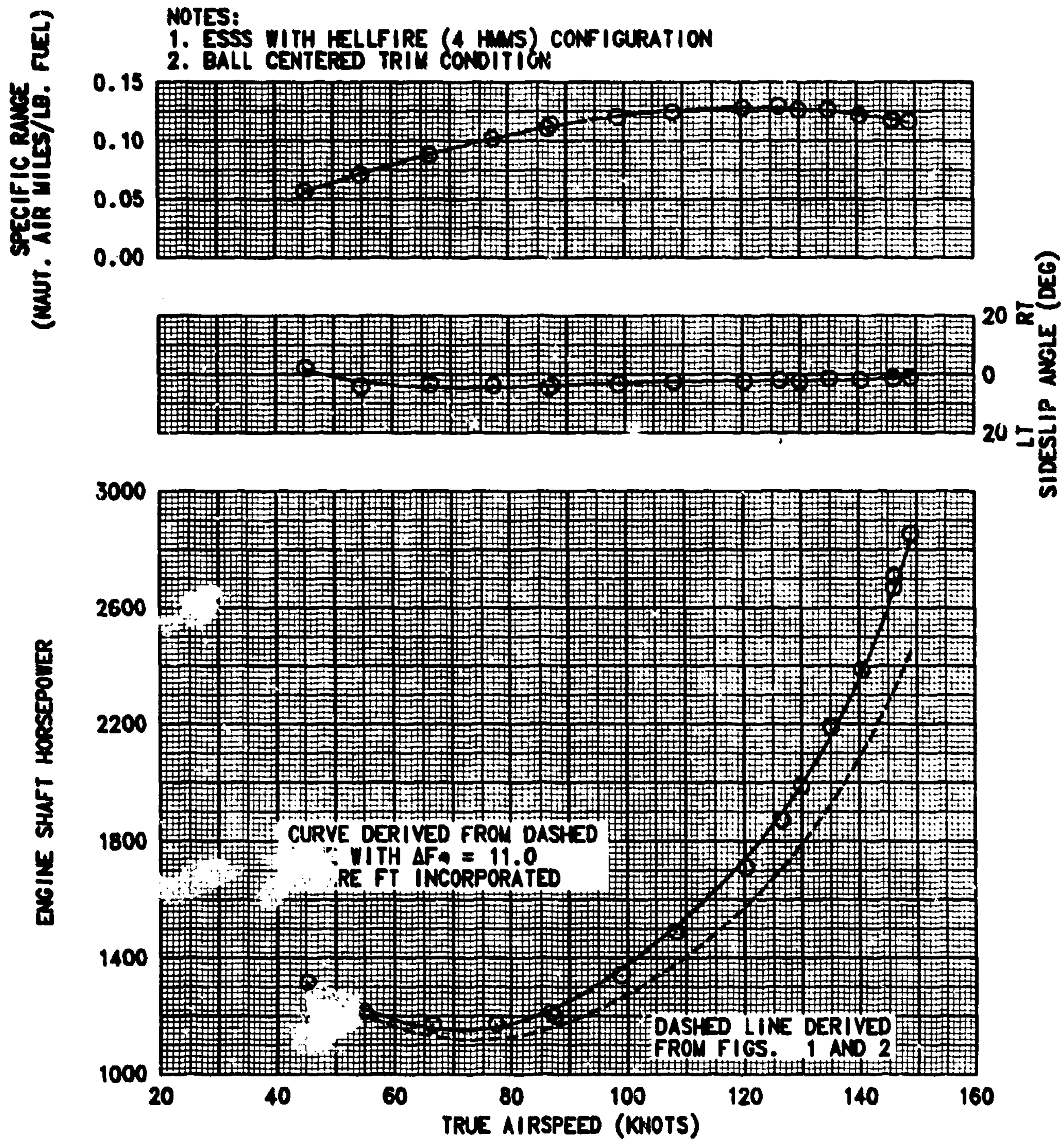


FIGURE 7

LEVEL FLIGHT PERFORMANCE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG COEFFICIENT OF THRUST
16850	349.6	0.3 RT	9110	10.0	257.8	0.007996

NOTES:
1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. BALL CENTERED TRIM CONDITION

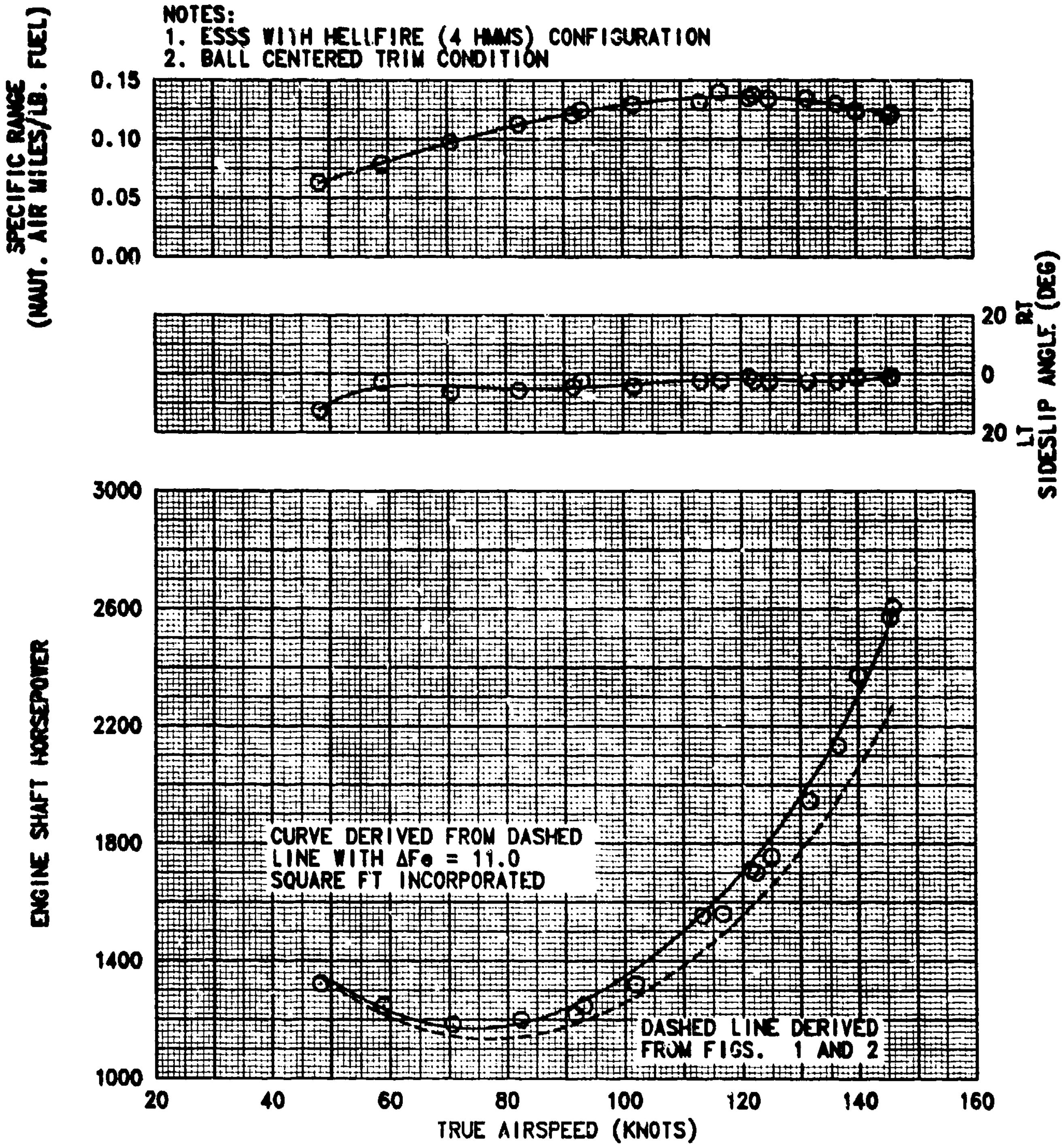


FIGURE 8

LEVEL FLIGHT PERFORMANCE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG COEFFICIENT OF THRUST
16980	350.1	0.3 RT	12190	6.5	257.6	0.009016

NOTES:
1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. BALL CENTERED TRIM CONDITION

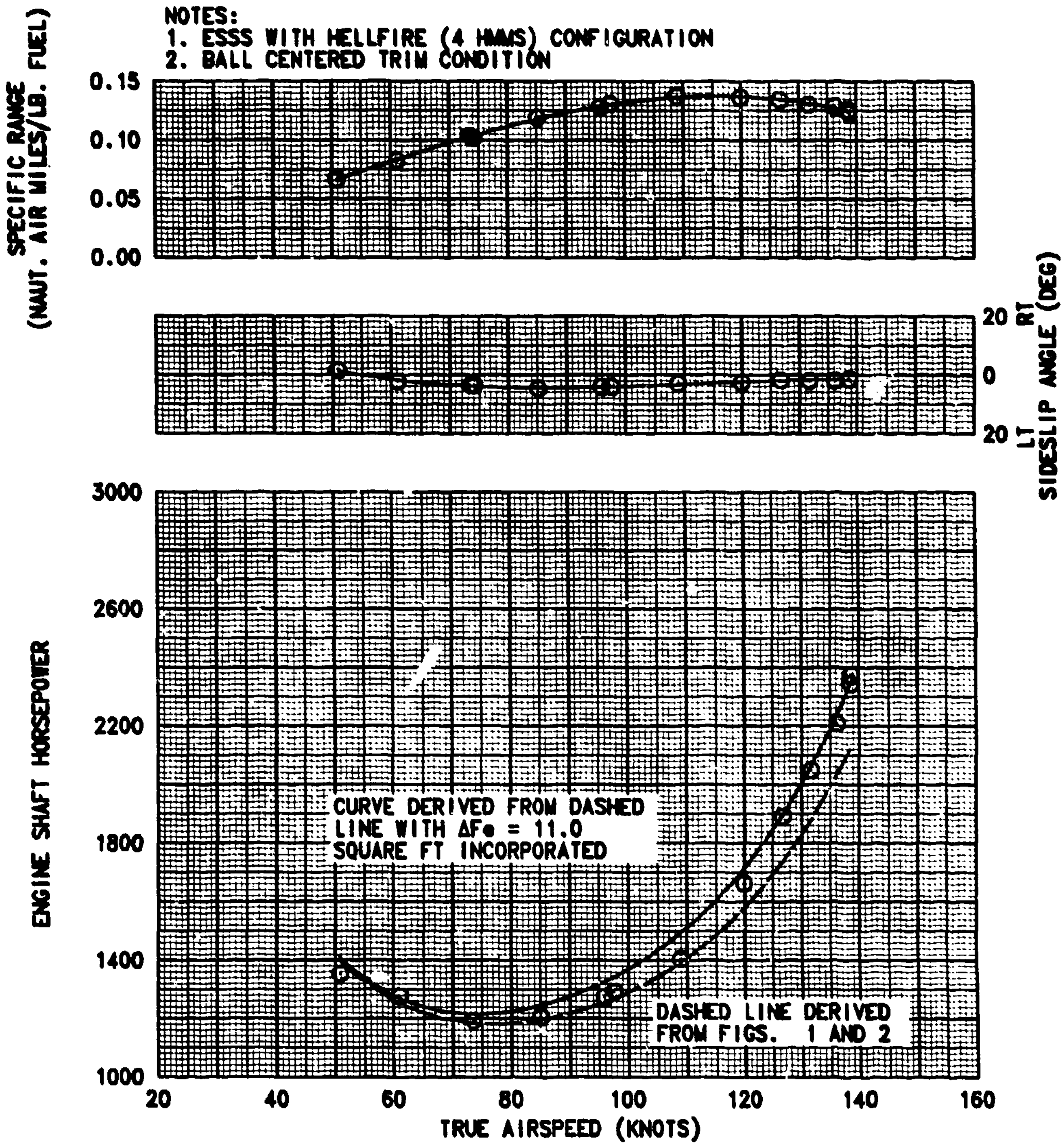


FIGURE 9

LEVEL FLIGHT PERFORMANCE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG COEFFICIENT OF THRUST
16810	349.2	0.3 RT	9330	11.5	257.9	0.007991

NOTES:
1. ESSS ONLY CONFIGURATION
2. BALL CENTERED TRIM CONDITION

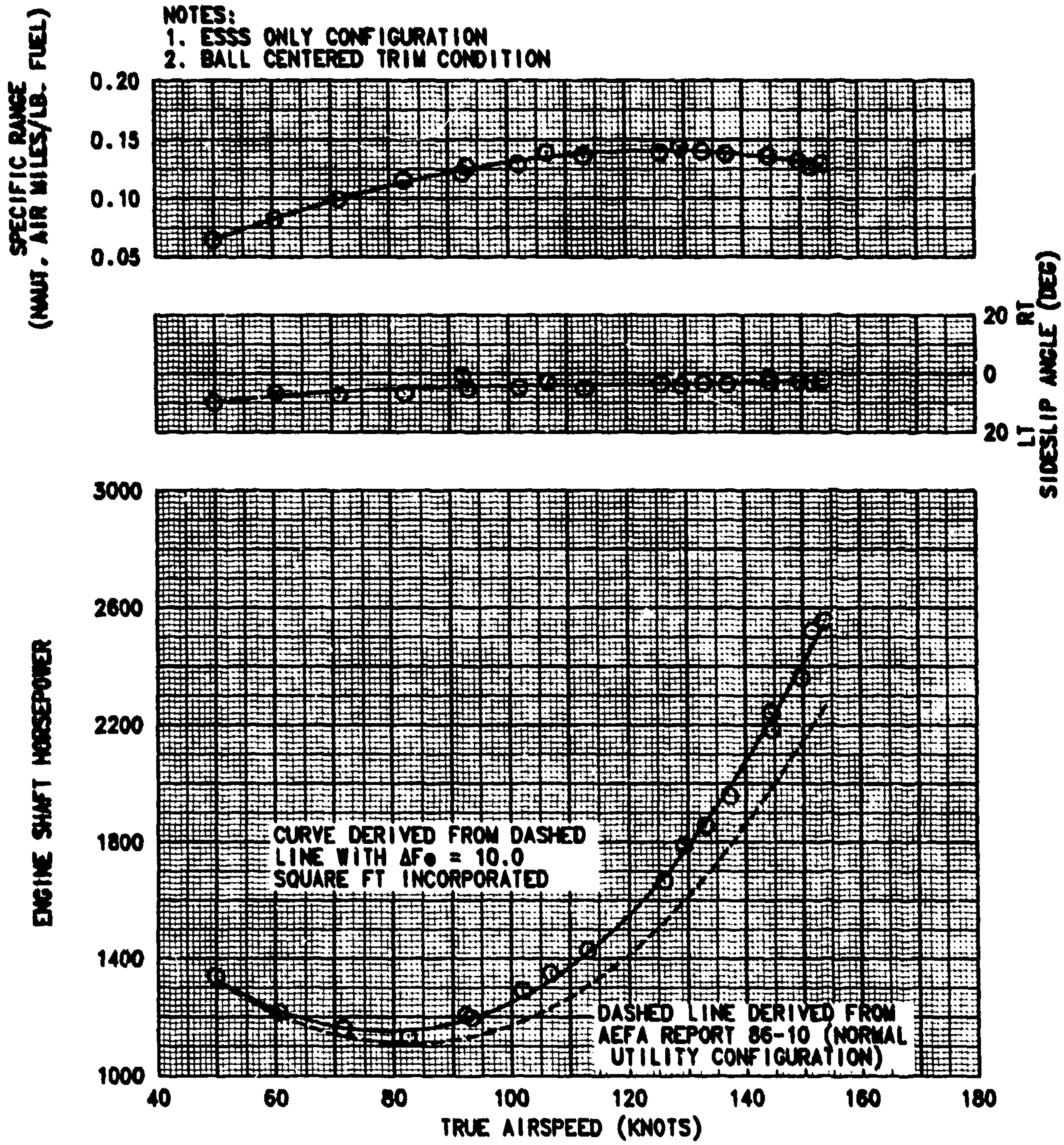


FIGURE 10
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG COEFFICIENT OF THRUST
16880	349.5	0.3 RT	12350	6.0	258.1	0.008978

NOTES:
1. ESSS ONLY CONFIGURATION
2. BALL CENTERED TRIM CONDITION

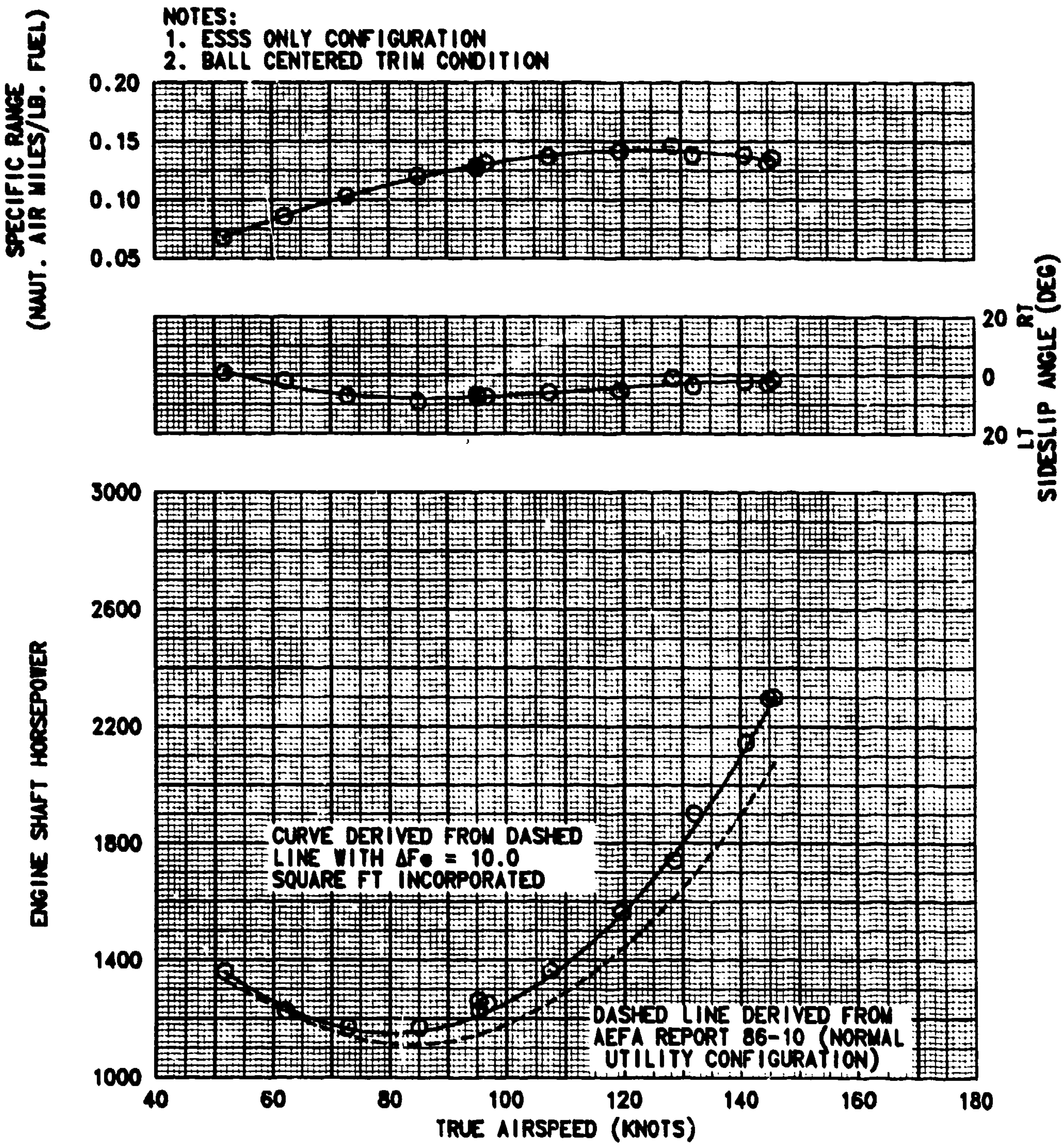


FIGURE 11

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFF.	AIRCRAFT CONFIGURATION
17010	390.1	0.3RT	5290	17.5	258	.007008	ESSS ONLY

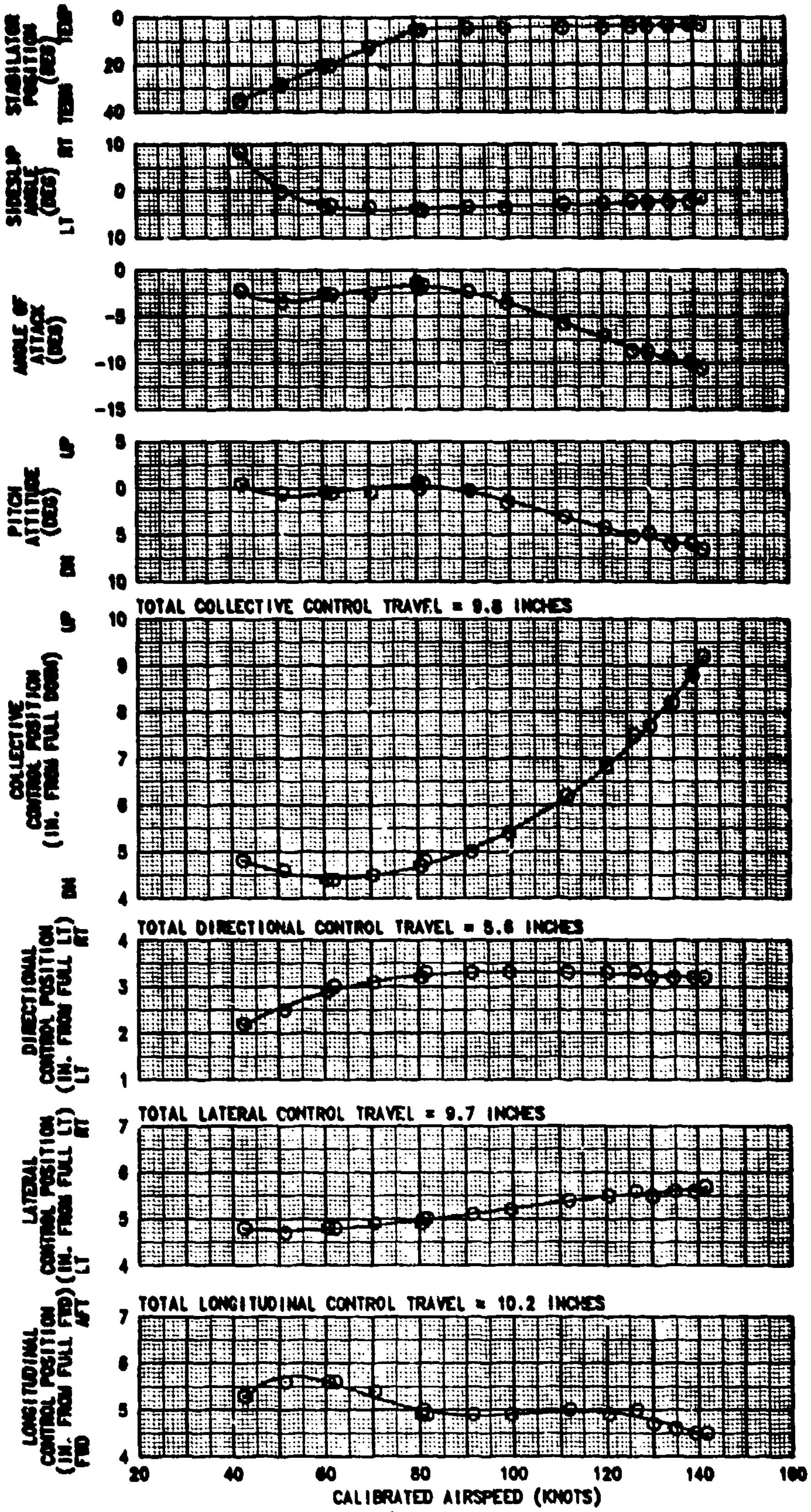


FIGURE 12
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFF.	AIRCRAFT CONFIGURATION
16810	349.2	0.3RT	9330	11.5	258	.007991	ESSS ONLY

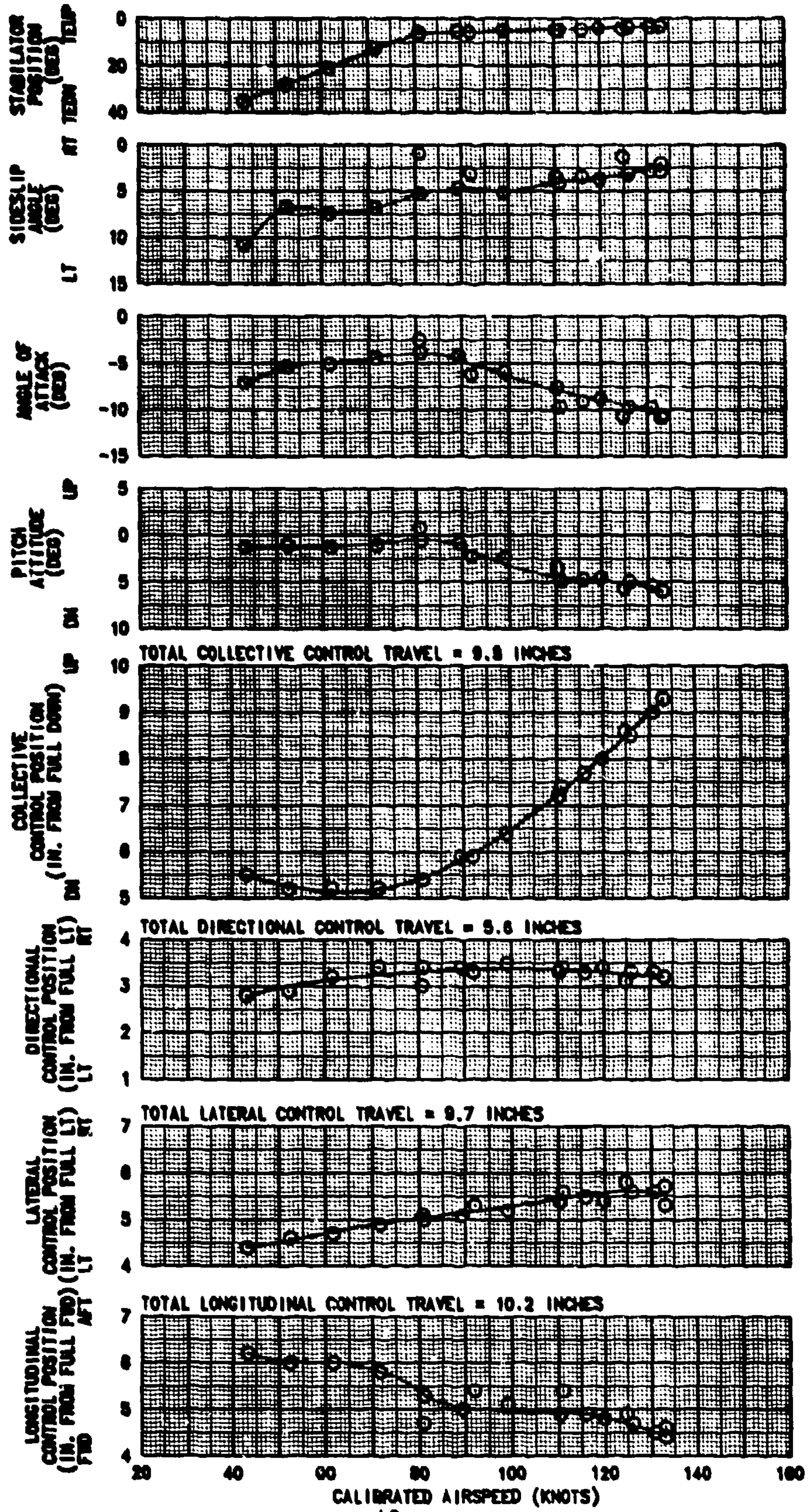


FIGURE 13

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFF.	AIRCRAFT CONFIGURATION
16880	349.5	0.3RT	12350	6.0	254	.008978	ESSS ONLY

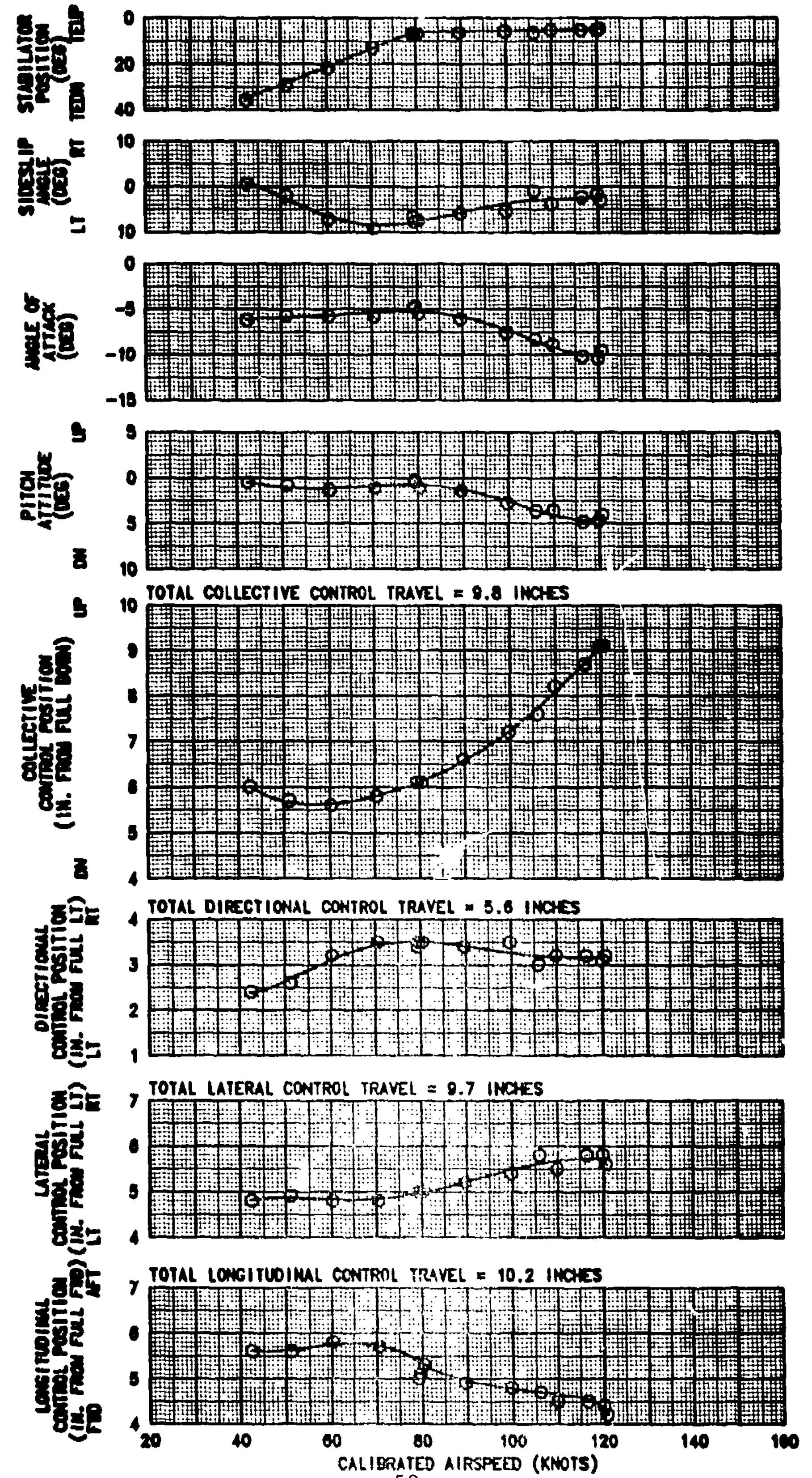


FIGURE 14

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFF.	AIRCRAFT CONFIGURATION
16950	350.0	0.3RT	5250	16.0	258	.006991	HELLFIRE

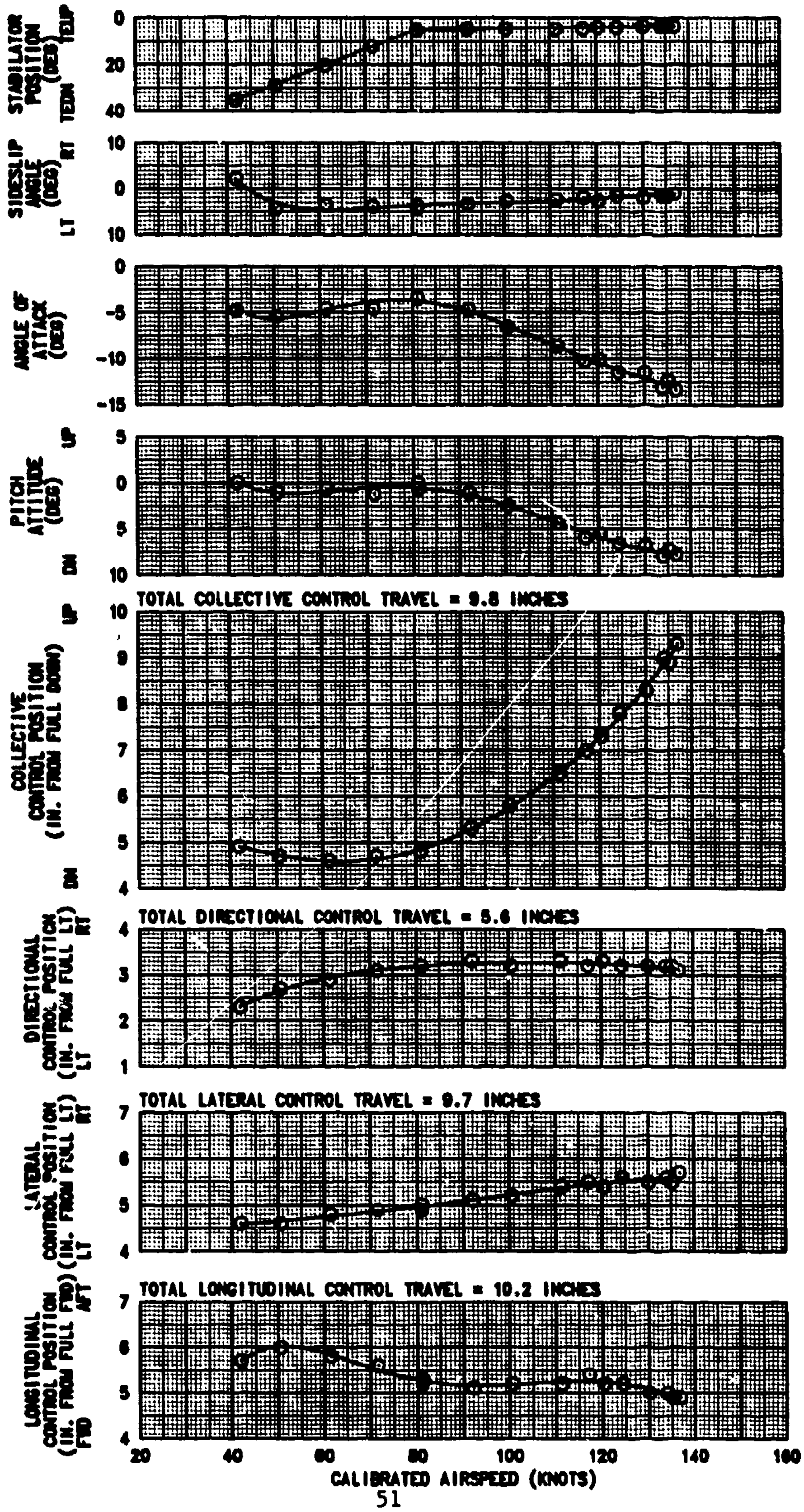


FIGURE 15
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFF.	AIRCRAFT CONFIGURATION
16850	349.6	0.3RT	9110	10.0	255	.007996	HELLFIRE

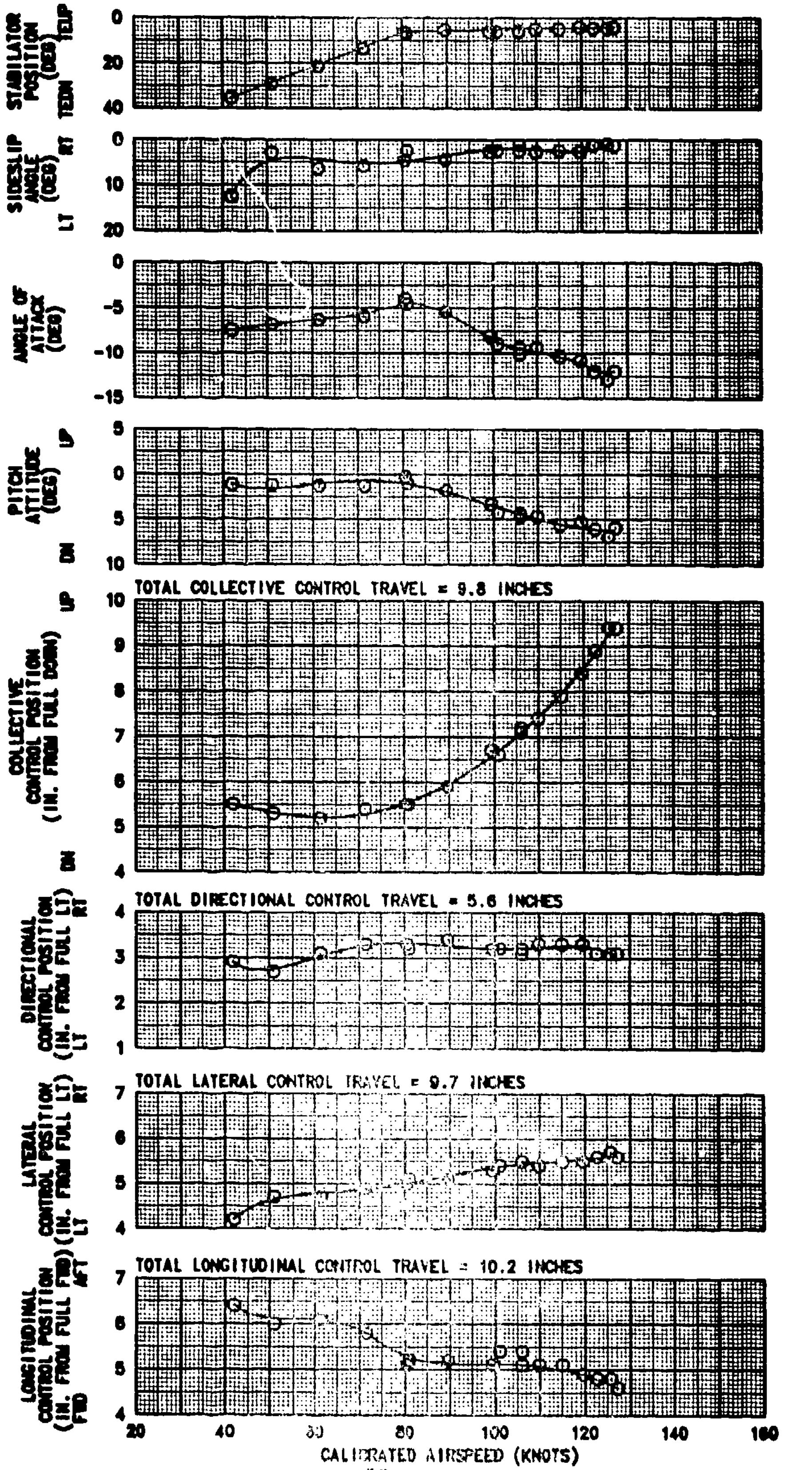


FIGURE 16
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFF.	AIRCRAFT CONFIGURATION
16980	350.1	0.3RT	12190	6.5	254	.009016	HELLFIRE

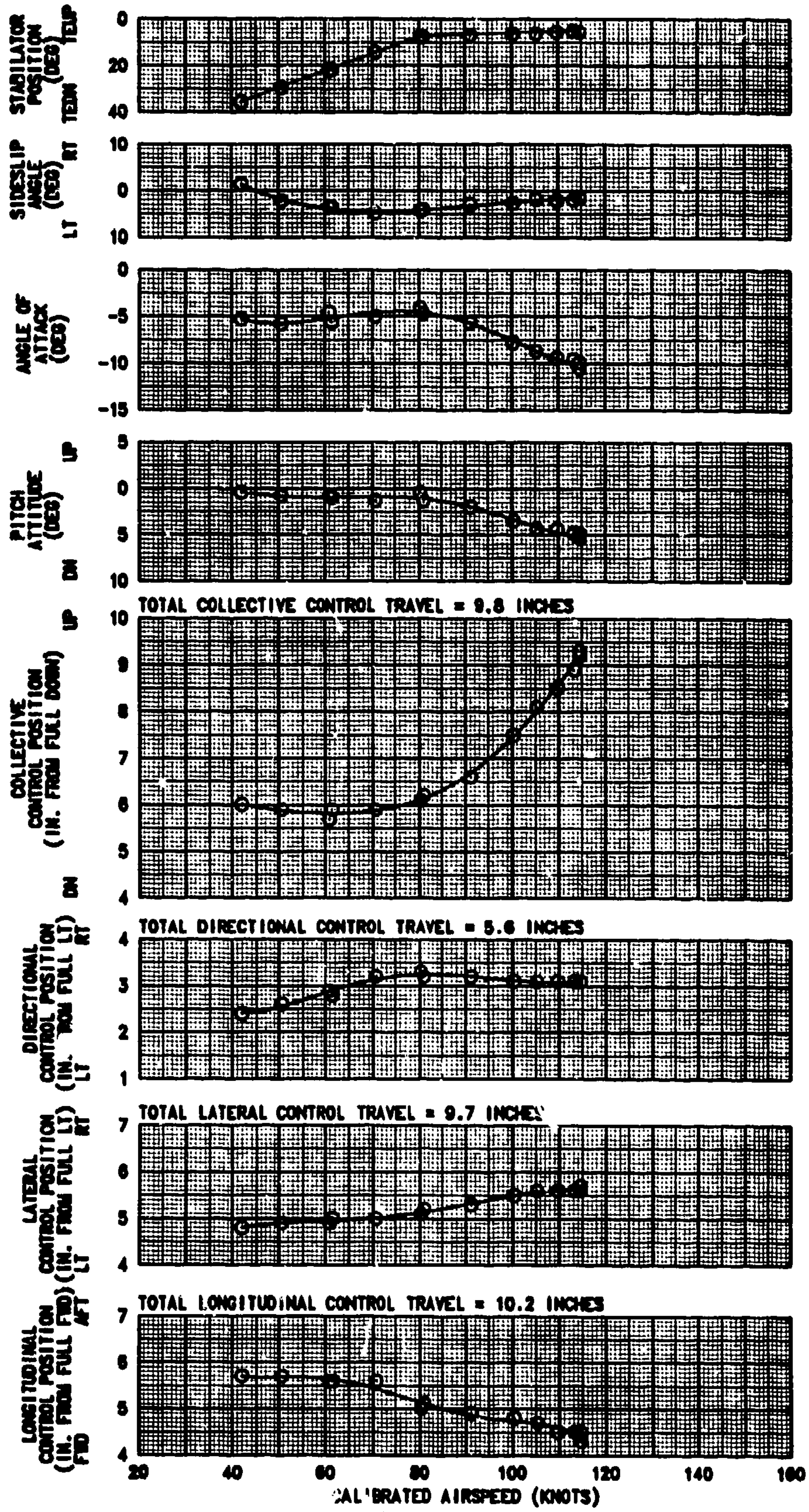


FIGURE 17
COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY
UH-60A USA S/N 84-23953

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
⊡	17110	350.8	0.3 RT	6110	14.5	258	100
⊙	16710	349.1	0.3 RT	6330	14.0	258	134

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. SHADED SYMBOLS DENOTE TRIM POINTS
4. BALL-CENTERED FLIGHT
5. PBA CENTERED AND LOCKED

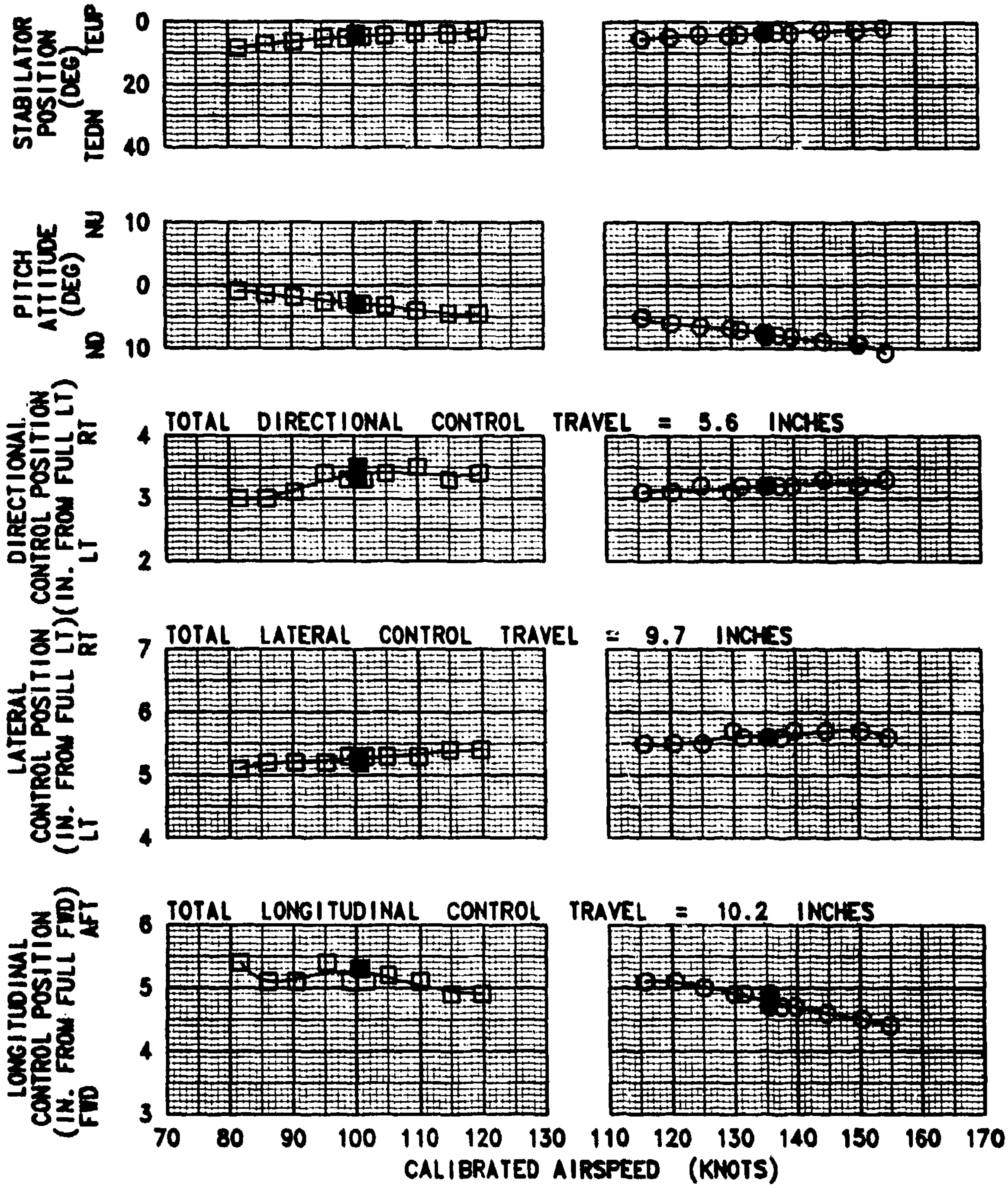


FIGURE 18

STATIC LATERAL-DIRECTIONAL STABILITY

UH-60A USA S/N 84-23953

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
□	16800	349.5	0.3 RT	6460	13.0	258	100
⊙	17020	350.4	0.3 RT	6360	13.5	258	132

NOTE:
1. ESSS WITH HELLFIRE (4 HMMS) INSTALLED
2. LEVEL FLIGHT
3. SHADED SYMBOLS DENOTE TRIM POINTS
4. PBA CENTERED AND LOCKED

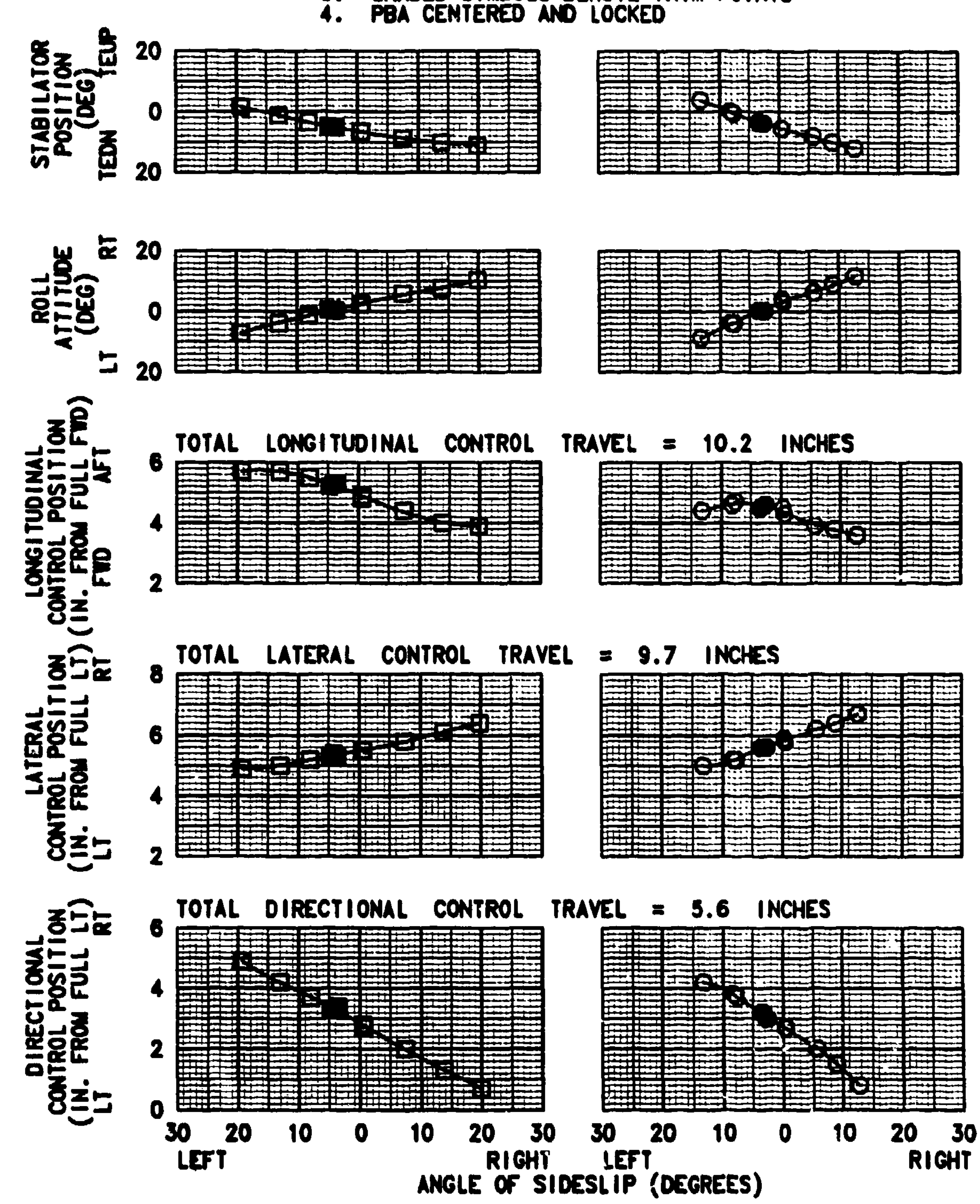


FIGURE 19
MANEUVERING STABILITY
UH-60A USA S/N 84-23953

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	TRIM FLIGHT CONDITION	SAS CONDITION
□	17310	351.7	0.3 RT	8090	12.5	258	99	RIGHT TURN	ON
⊙	17070	350.7	0.3 RT	7620	13.5	258	101	LEFT TURN	ON

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. SHADED SYMBOLS DENOTE TRIM POINT
3. PBA CENTERED AND LOCKED

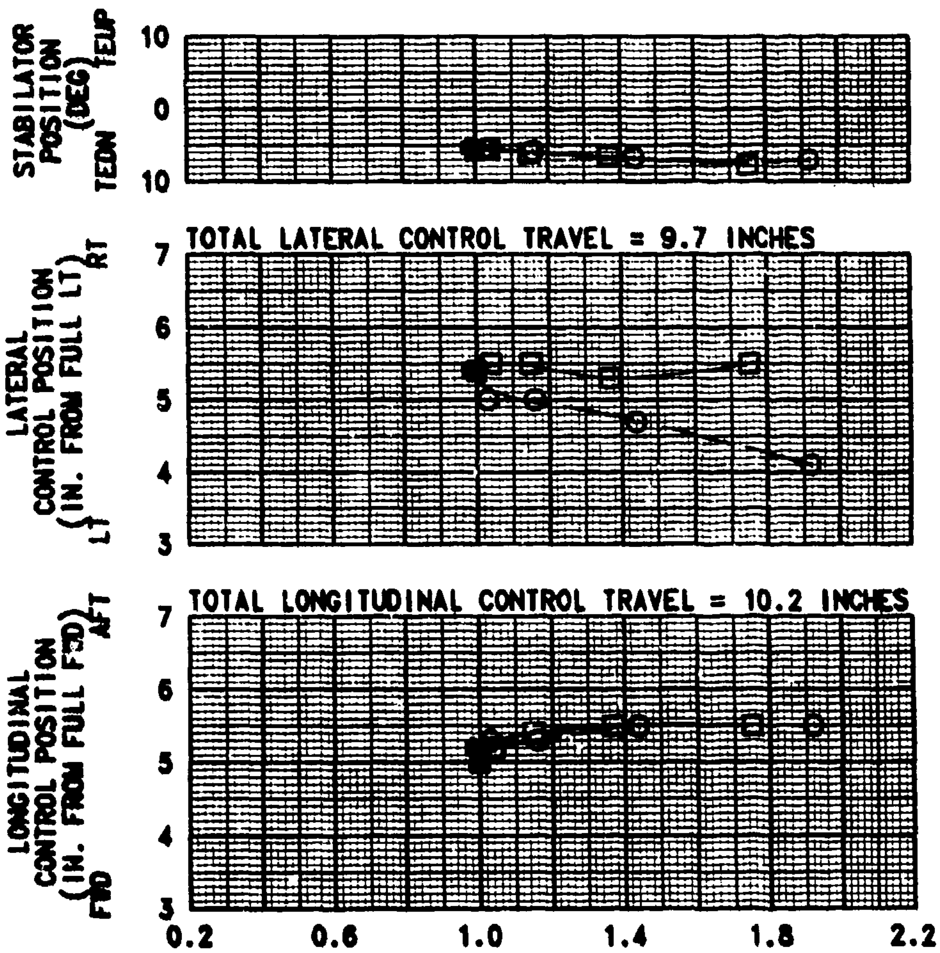


FIGURE 20
MANEUVERING STABILITY
UH-60A USA S/N 84-23953

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	TRIM FLIGHT CONDITION	SAS CONDITION
⊡	16780	349.5	0.3 RT	7740	13.0	258	129	RIGHT TURN	ON
⊙	16560	348.5	0.3 RT	7320	14.0	258	128	LEFT TURN	ON

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. SHADED SYMBOLS DENOTE TRIM POINT
3. PBA CENTERED AND LOCKED

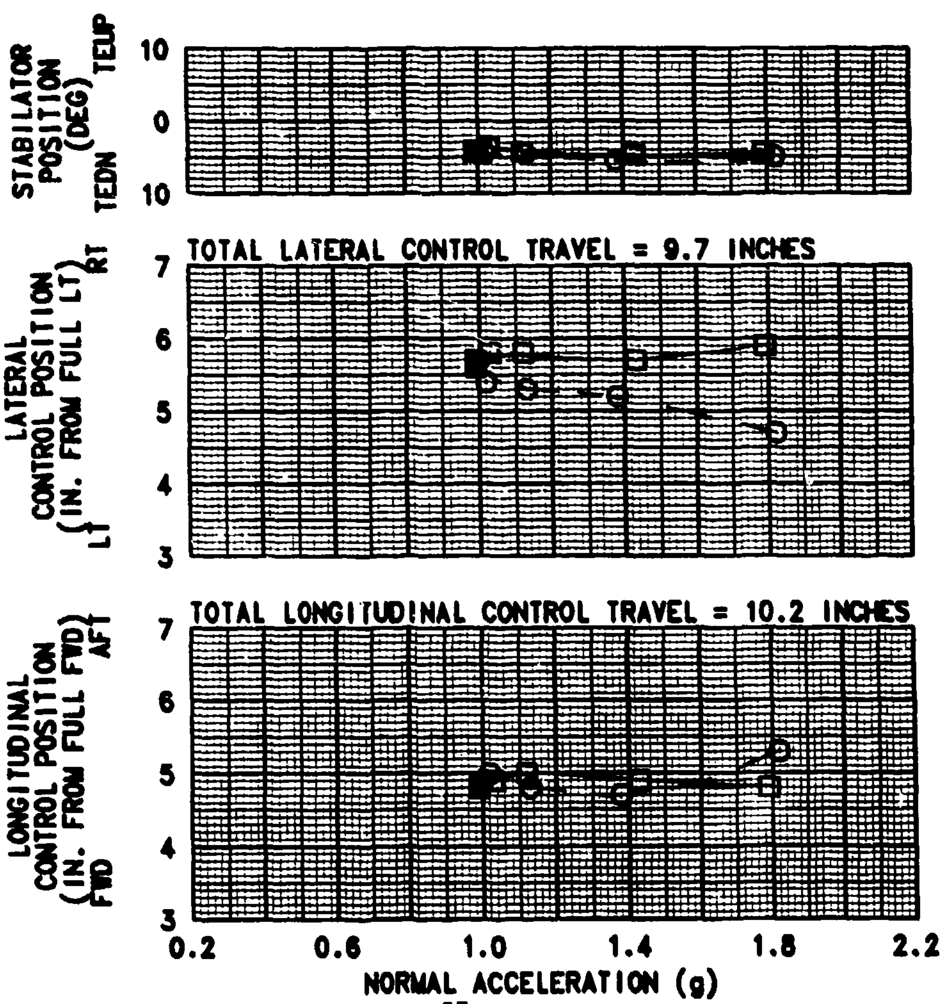


FIGURE 21
MANEUVERING STABILITY
SYMMETRICAL PUSHOVERS AND PULLUPS
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
17320	351.7	0.3 RT	6450	15.5	258	98	ON

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. PBA CENTERED AND LOCKED

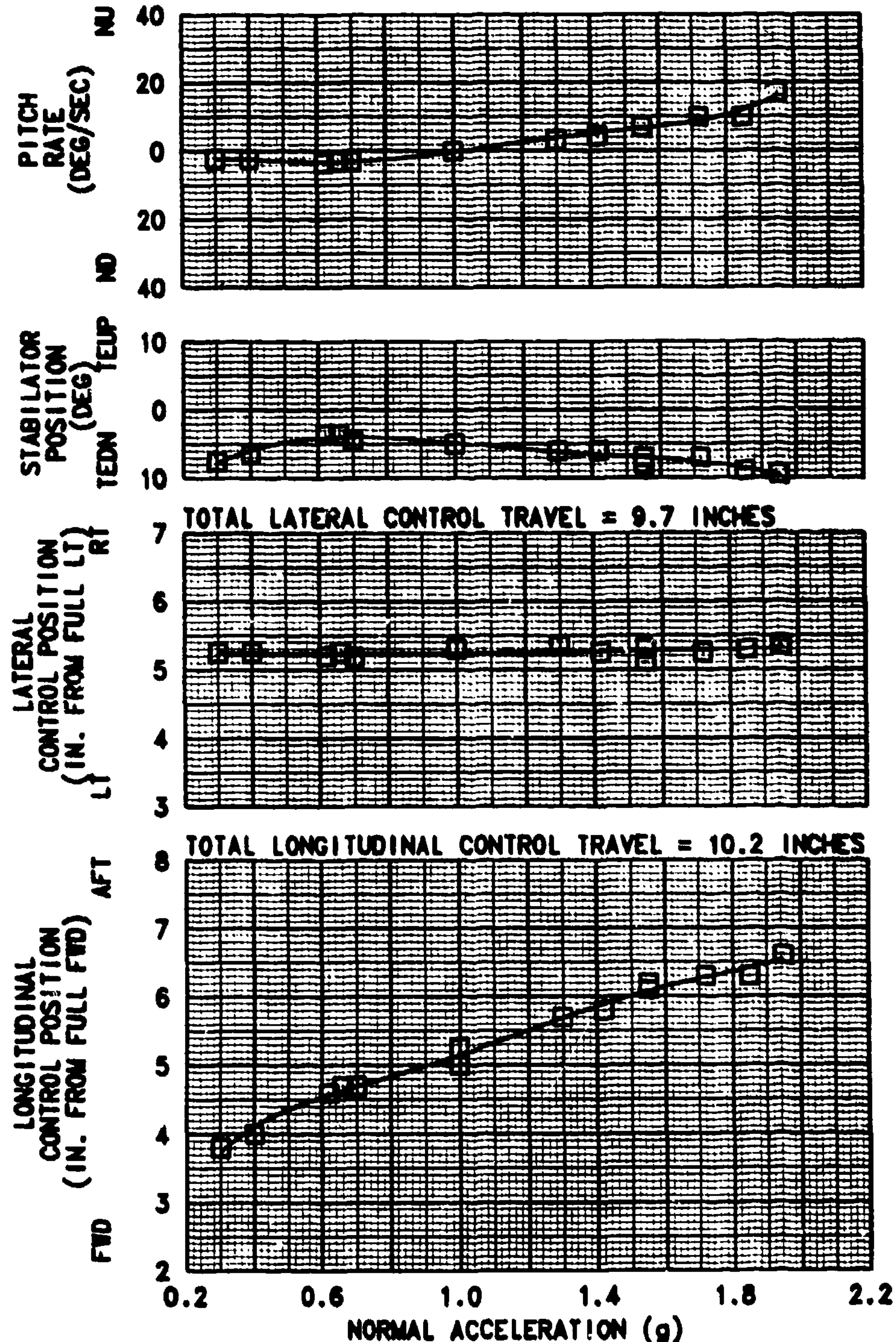


FIGURE 22

MANEUVERING STABILITY

SYMMETRICAL PUSHOVERS AND PULLUPS

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
16860	349.8	0.3 RT	6490	15.5	258	131	ON

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. PBA CENTERED AND LOCKED

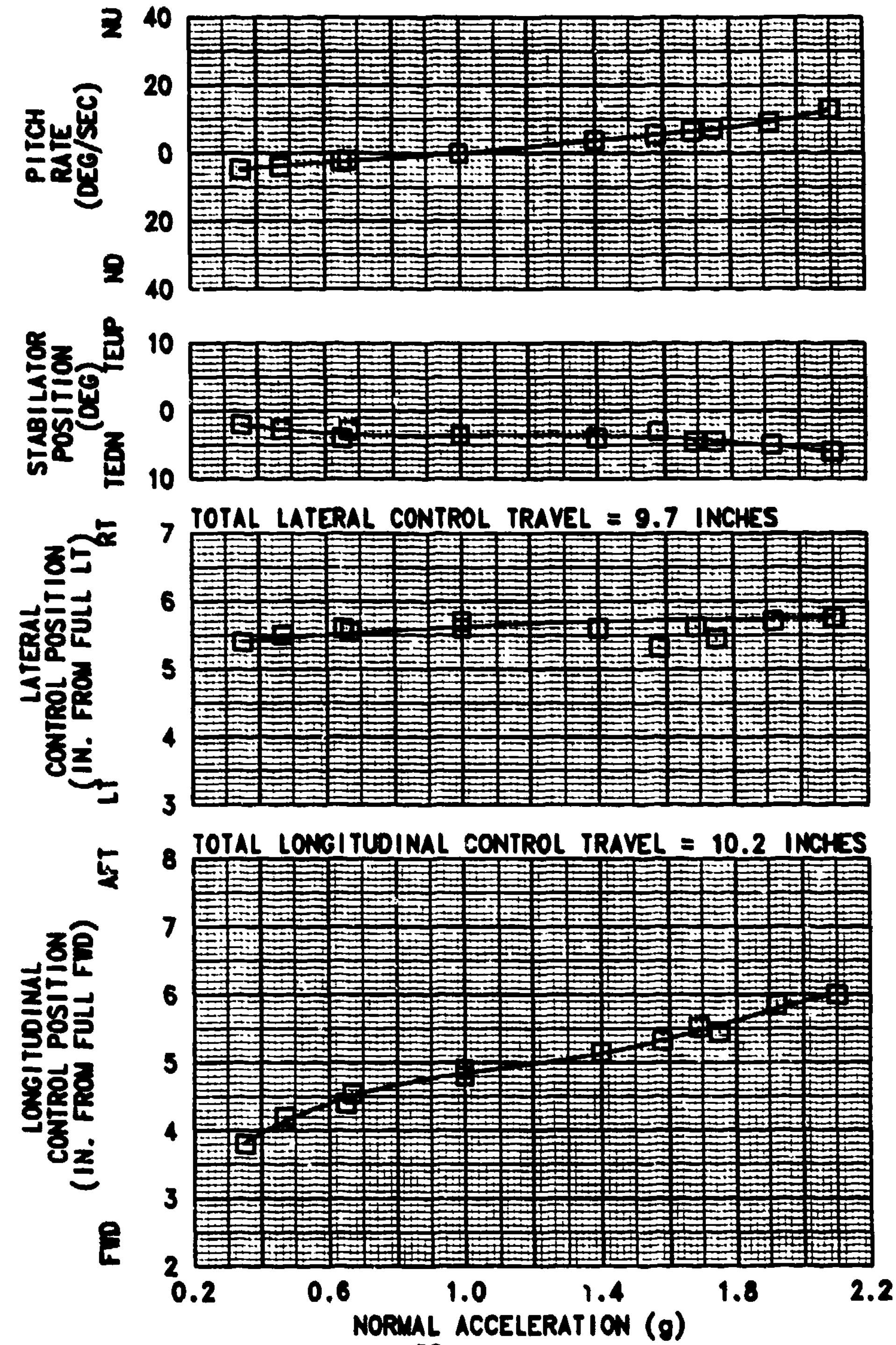


FIGURE 73

AFT LONGITUDINAL PULSE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
1660	348.7	0.3 RT	6790	15.0	258	139	ON

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. PBA CENTERED AND LOCKED

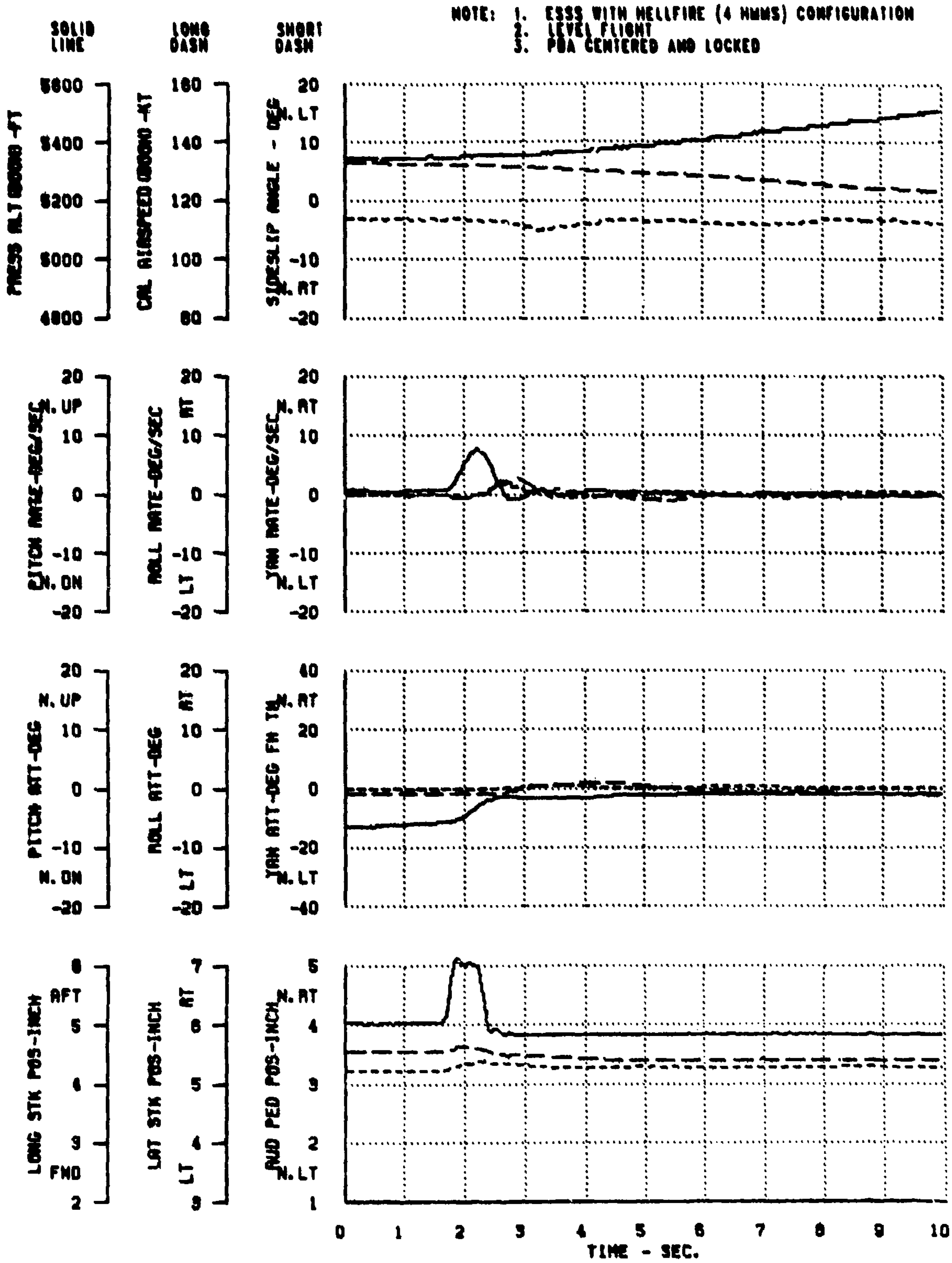


FIGURE 24
RIGHT LATERAL PULSE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
[illegible]	350.4	0.3 RT	6410	16.0	258	101	ON

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. PBA CENTERED AND LOCKED

SOLID LINE LONG DASH SHORT DASH

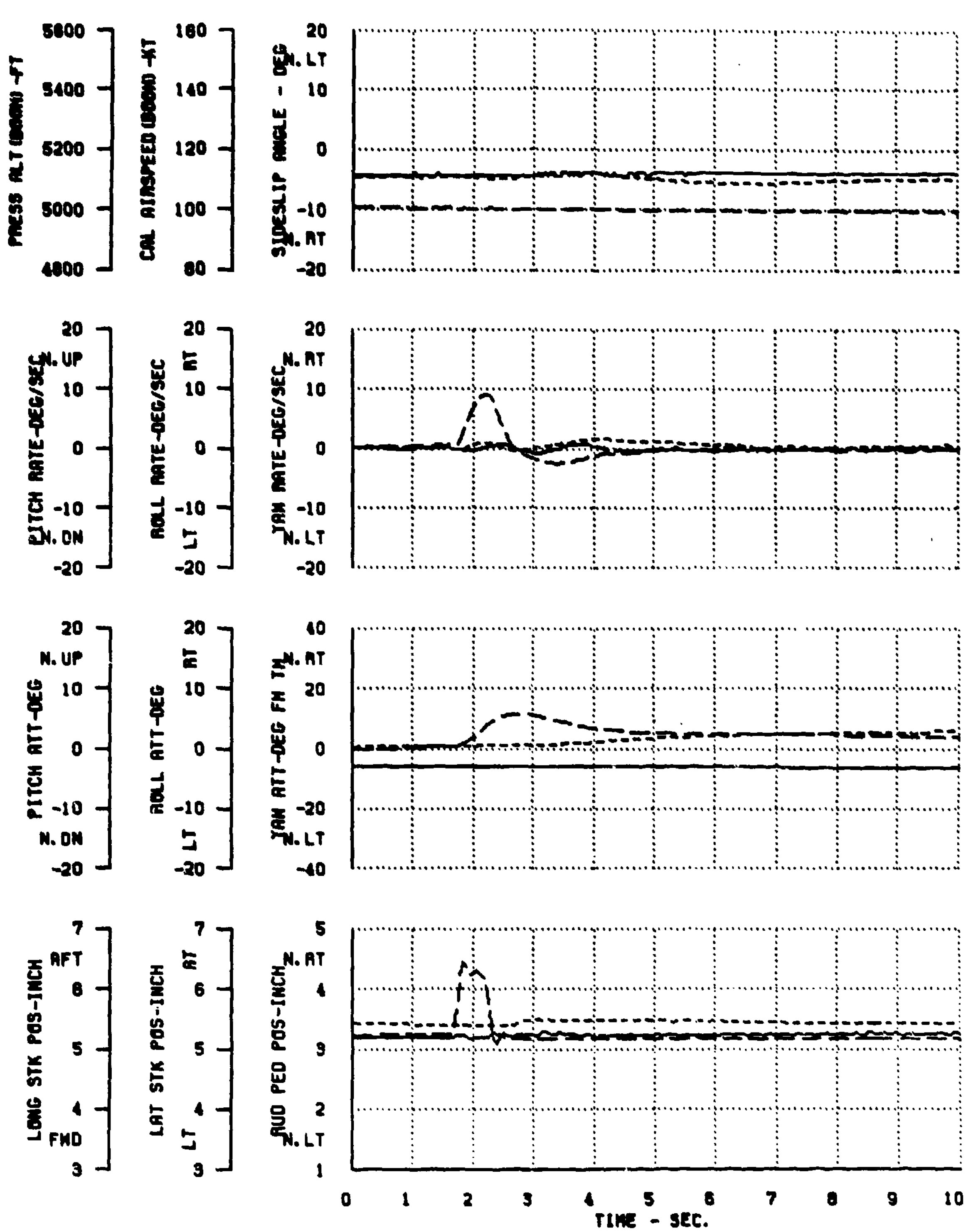


FIGURE 25
RIGHT PEDAL PULSE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
1700	350.1	0.3 RT	6300	15.5	258	102	ON

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. PBA CENTERED AND LOCKED

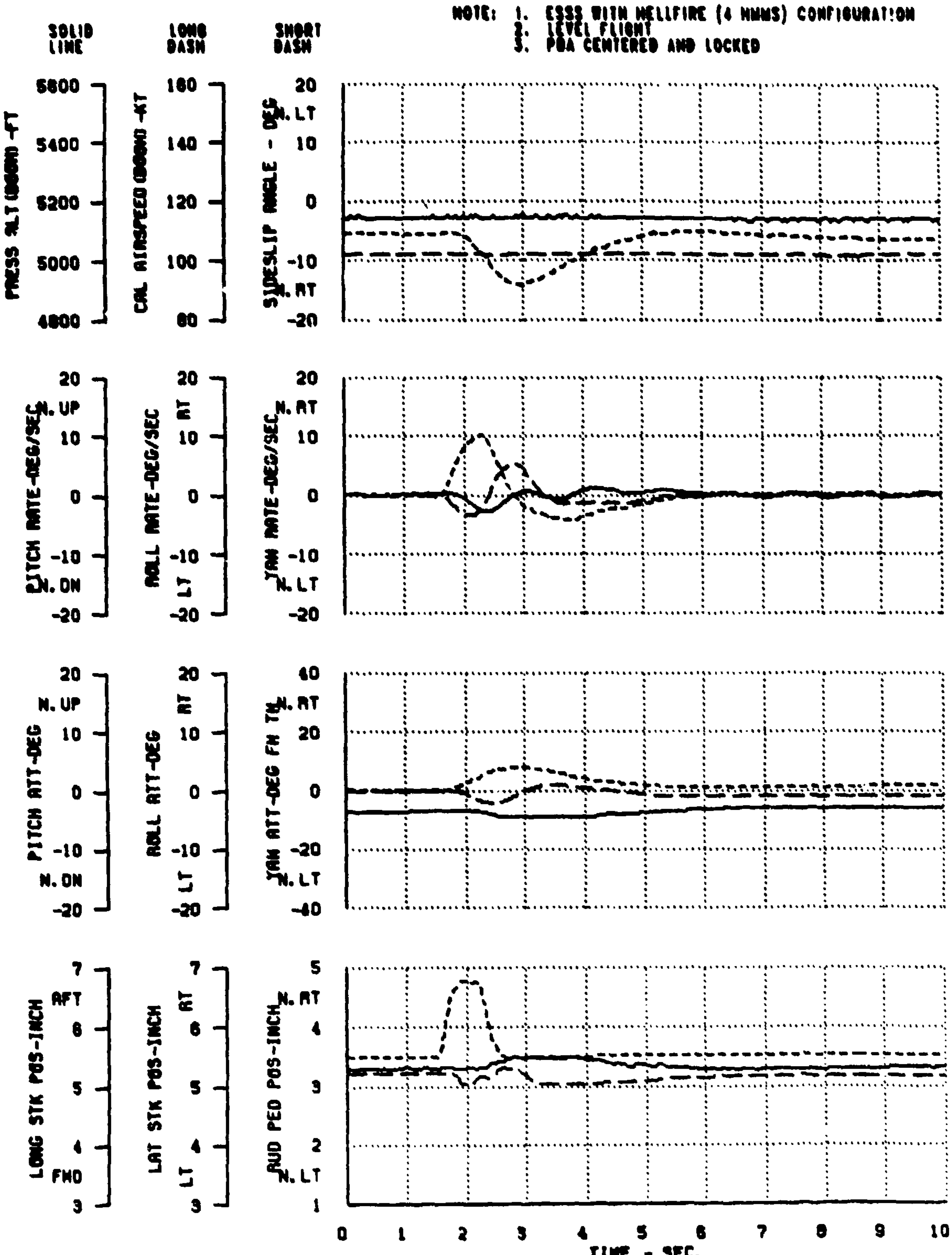


FIGURE 26

FORWARD LONGITUDINAL PULSE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
1690	349.9	0.3 RT	6190	16.0	258	100	OFF

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. PBA CENTERED AND LOCKED

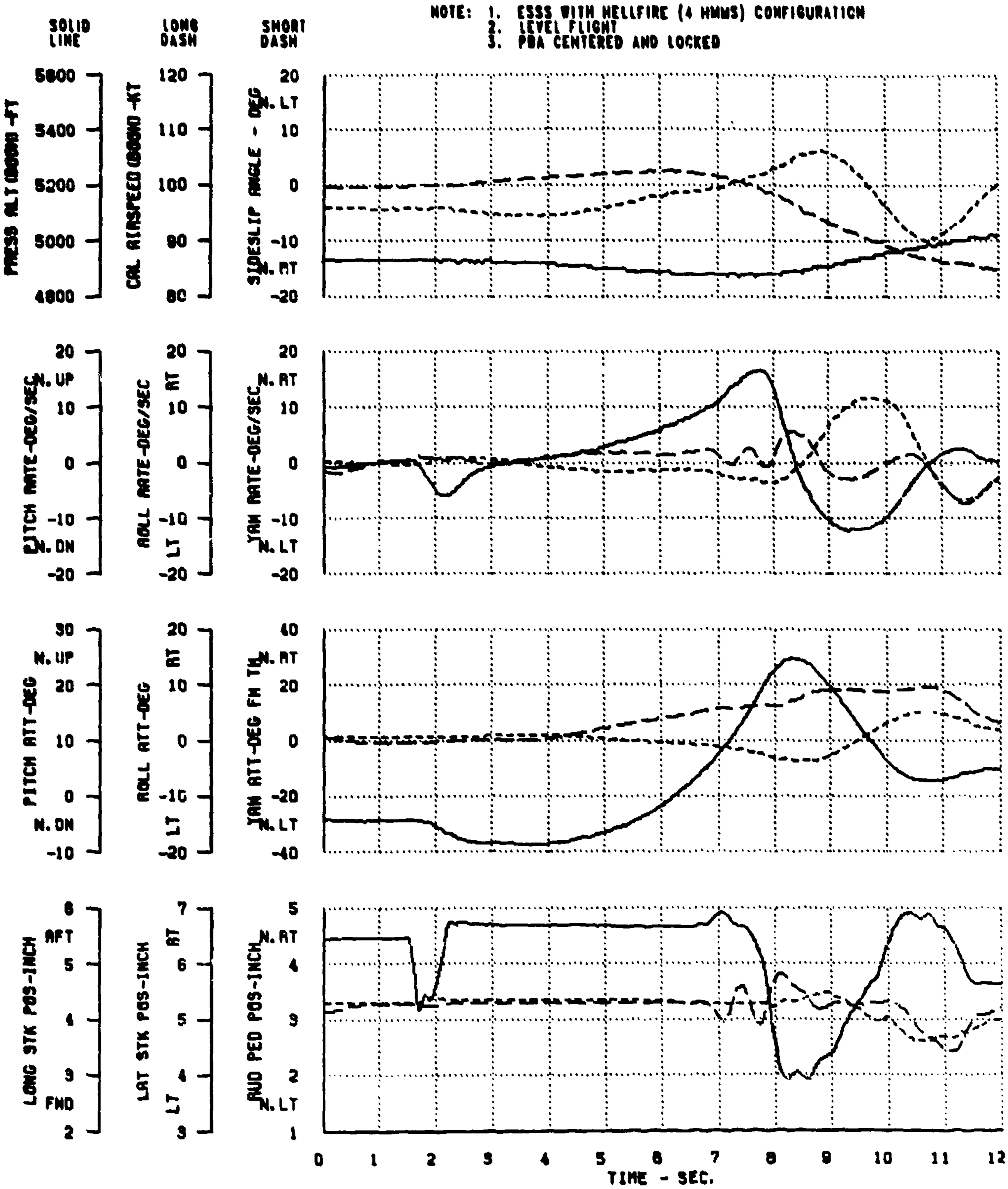


FIGURE 27
ONE INCH FORWARD PULSE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
1730	351.6	0.3 RT	61[illegible]0	16.5	259	135	OFF

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. PBA CENTERED AND LOCKED

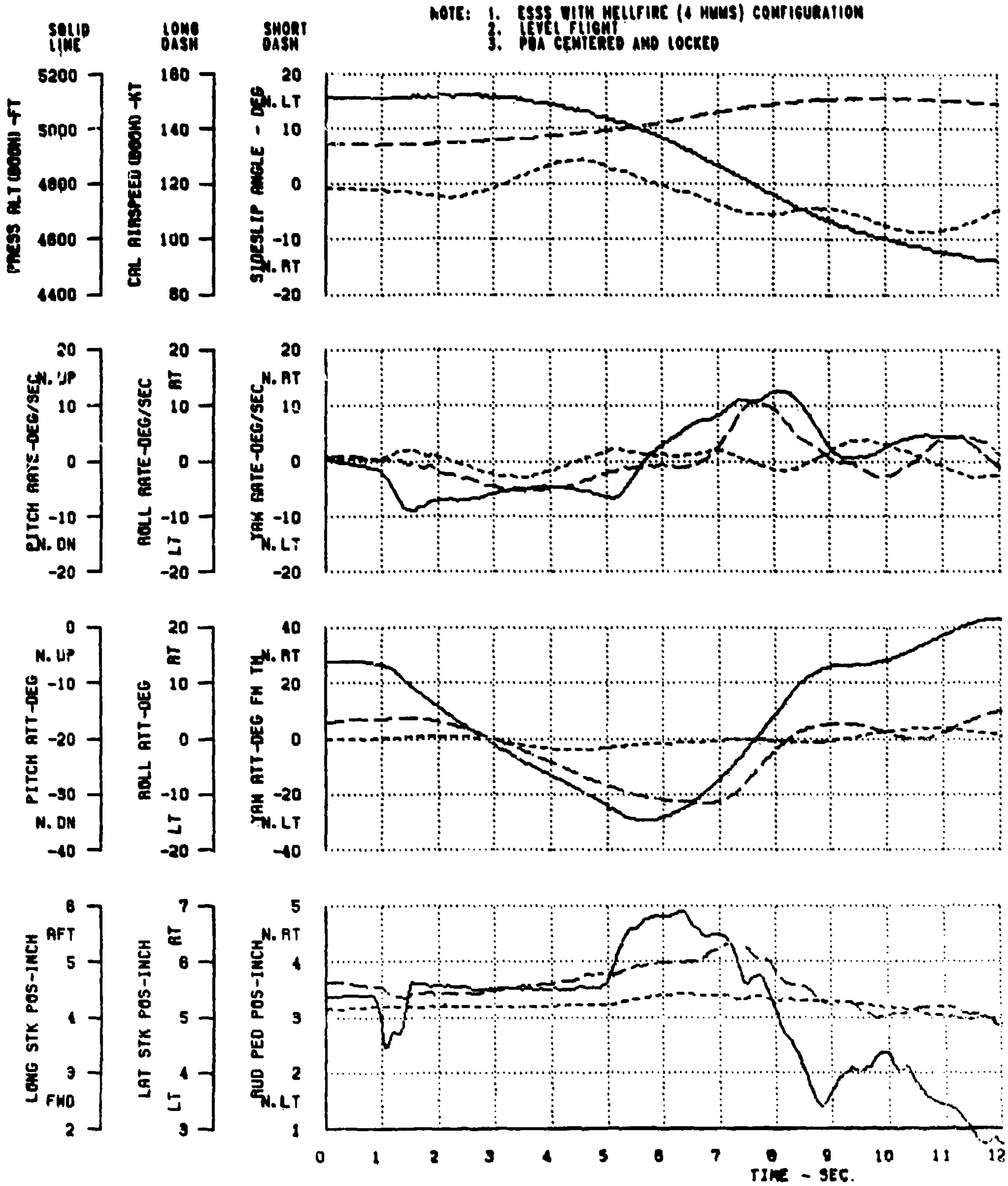


FIGURE 28
FORWARD LONGITUDINAL PULSE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
1650	348.1	0.3 RT	6860	15.0	257	133	OFF

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. PBA CENTERED AND LOCKED

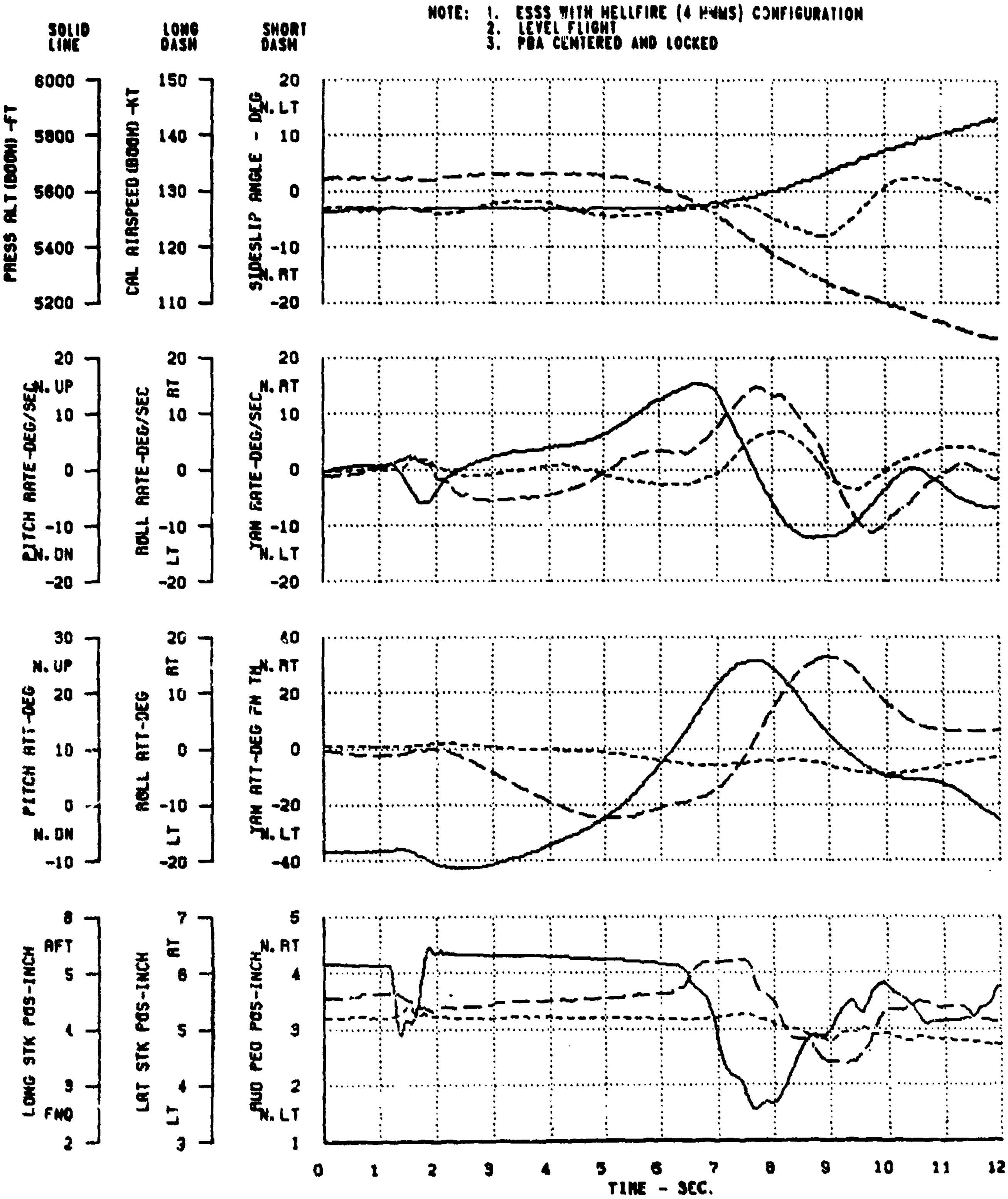


FIGURE 29
AFT LONGITUDINAL PULSE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
1690	349.8	0.3 RT	6530	15.5	258	99	OFF

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. PBA CENTERED AND LOCKED

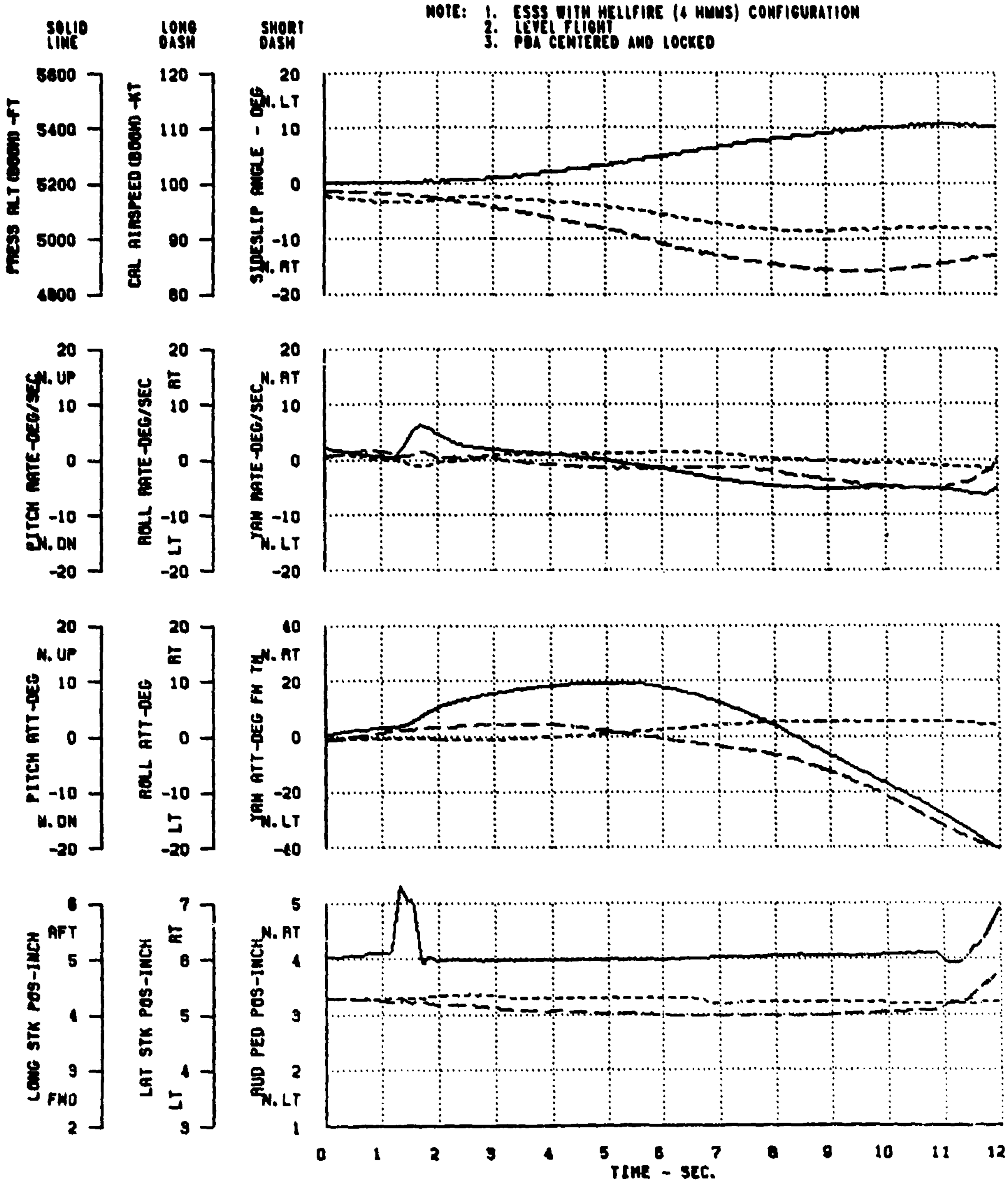


FIGURE 38

AFT LONGITUDINAL PULSE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
1640	347.9	0.3 RT	6940	15.5	254	133	OFF

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. PBA CENTERED AND LOCKED

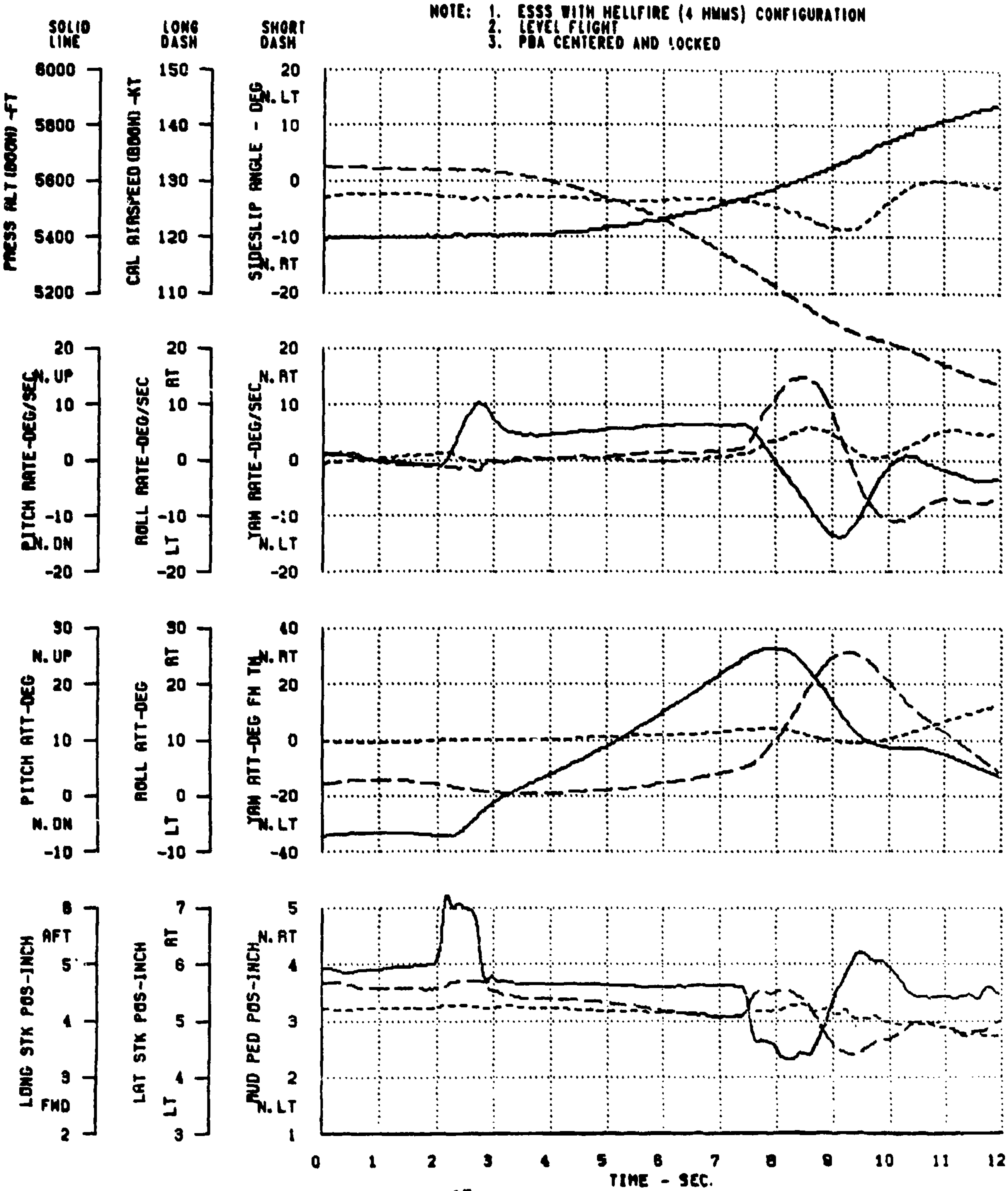


FIGURE 31

LEFT LATERAL PULSE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
1380	349.7	0.3 RT	6520	15.5	258	103	OFF

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. PBA CENTERED AND LOCKED

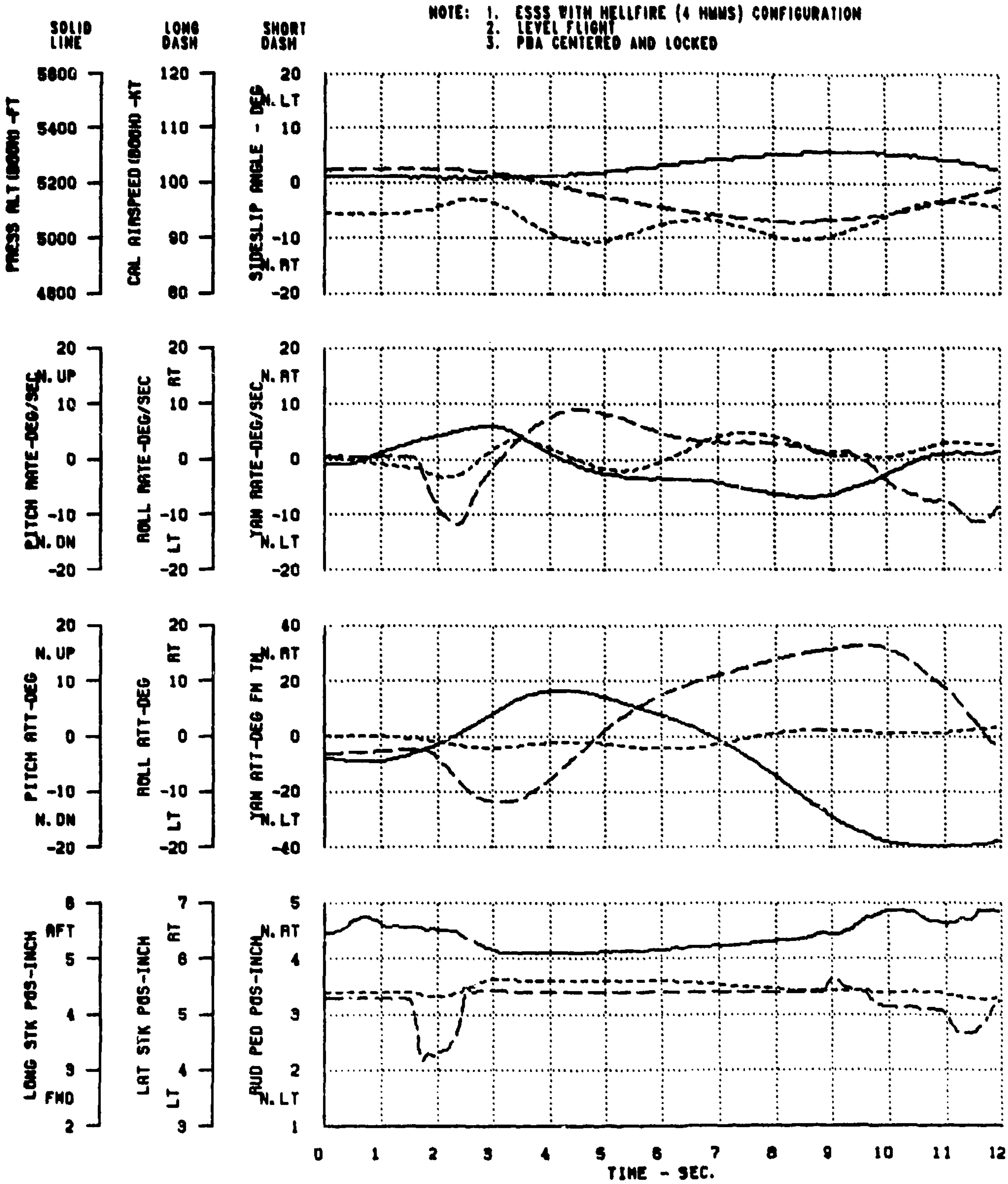


FIGURE 32

LEFT LATERAL PULSE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
1640	347.8	0.3 RT	7380	15.0	255	132	OFF

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. PBA CENTERED AND LOCKED

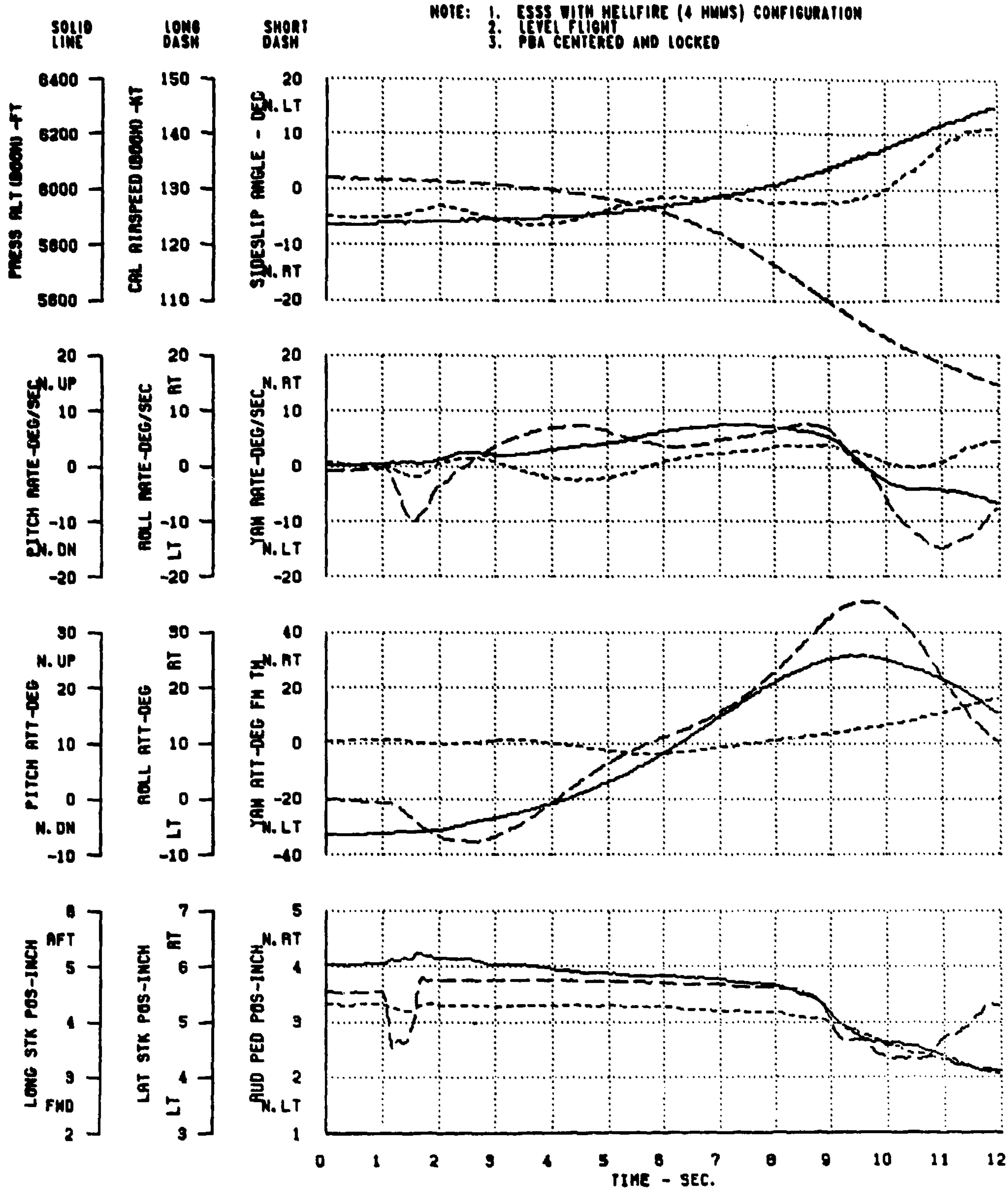


FIGURE 33
LEFT PEDAL PULSE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
1670	349.2	0.3 RT	6110	16.0	258	90	OFF

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. PBA CENTERED AND LOCKED

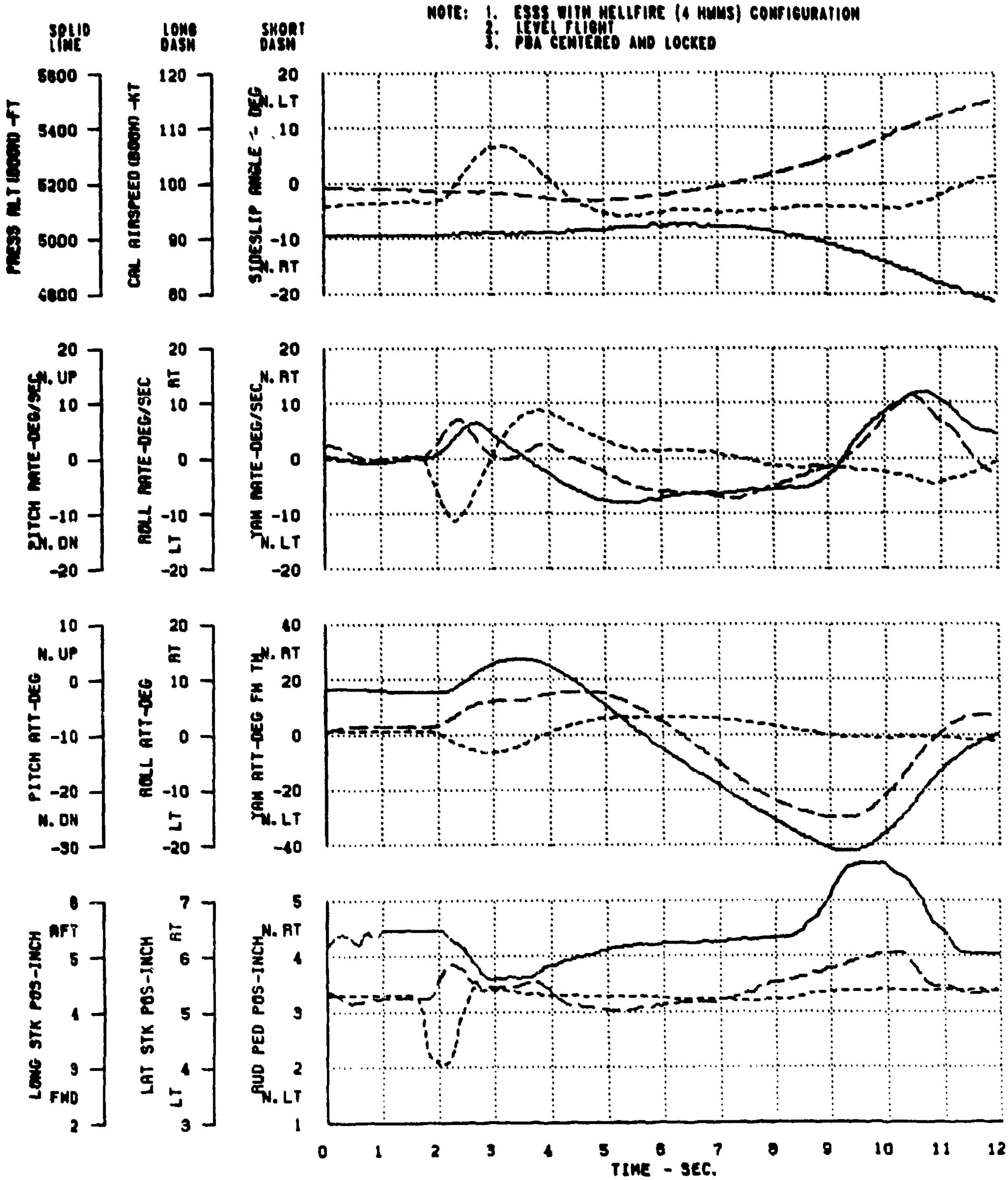


FIGURE 34

LEFT PEDAL PULSE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
1690	350.1	0.3 RT	6260	16.0	258	134	OFF

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. PBA CENTERED AND LOCKED

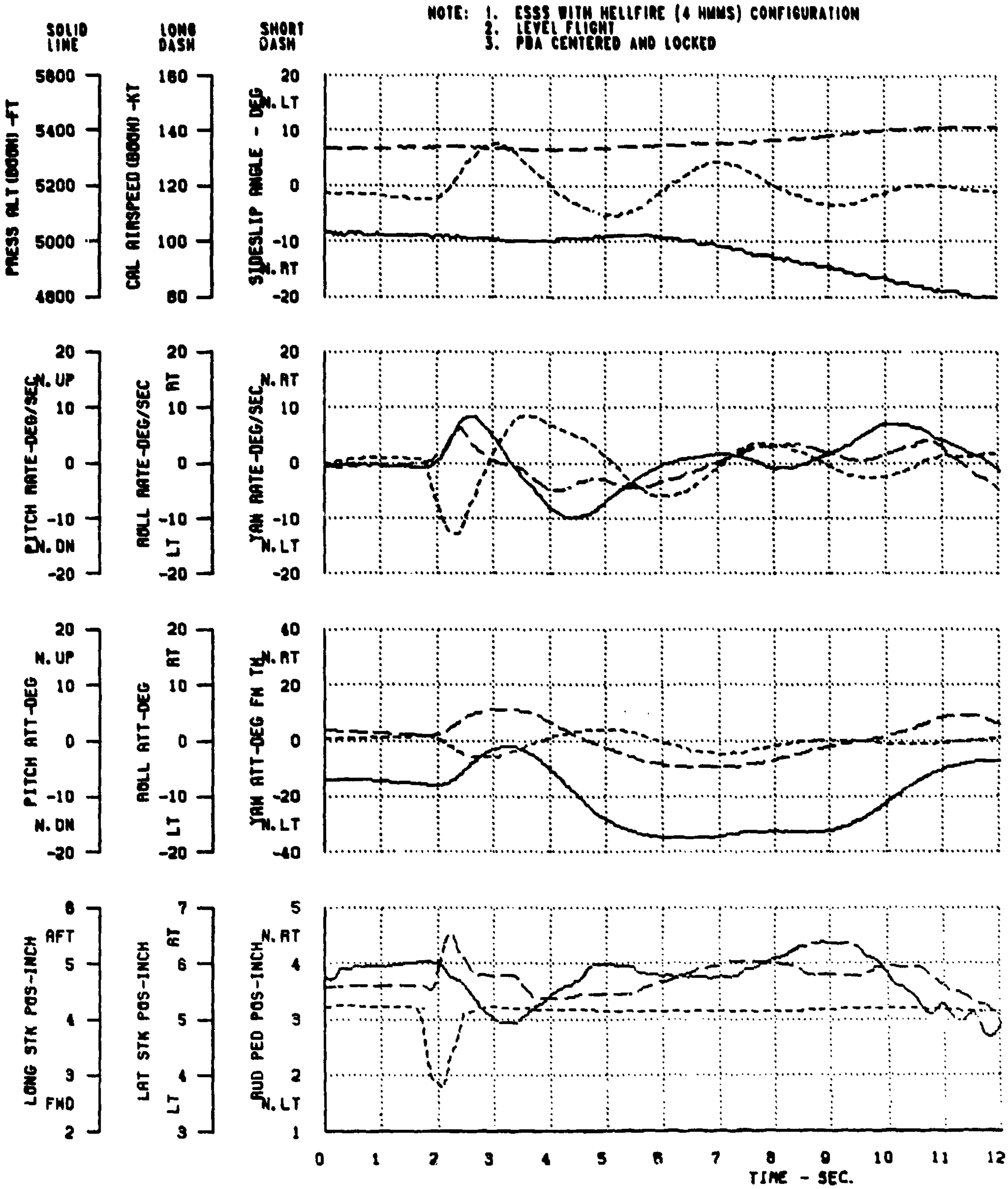


FIGURE 38

LOW SPEED FORWARD AND REARWARD FLIGHT CHARACTERISTICS

UH-60A USA S/N 84-23953

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG WHEEL HEIGHT (FT)	AIRCRAFT CONFIGURATION
◻	17040	351.0	0.3 RT	1470	27.5	258	30	HELLFIRE
○	17010	350.9	0.3 RT	1200	25.0	258	30	HELLFIRE

NOTE: 1. VERTICAL LINES DENOTE CONTROL EXCURSIONS
2. FBA CENTERED AND LOCKED

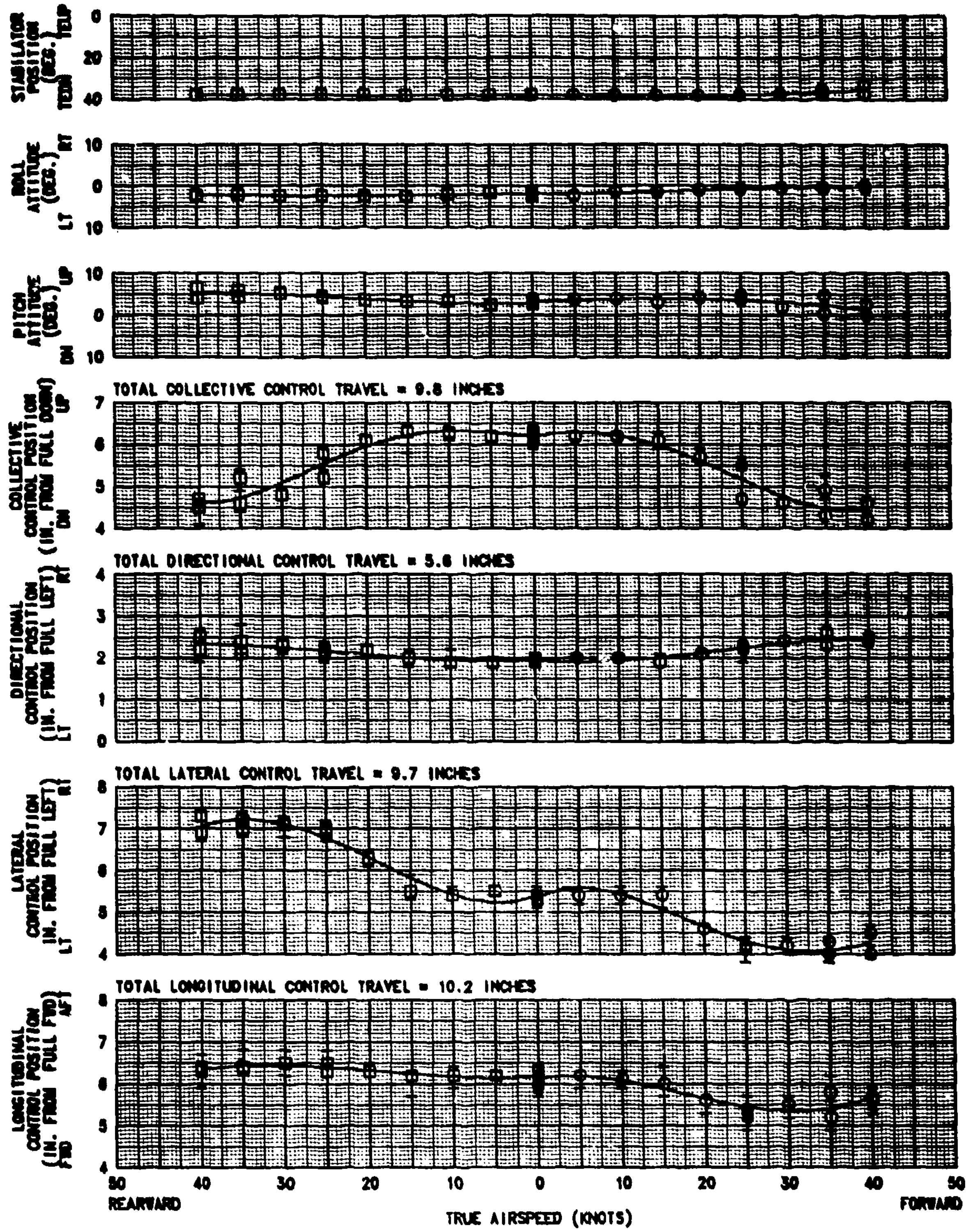


FIGURE 38

LOW SPEED RIGHT AND LEFT SIDEWARD FLIGHT CHARACTERISTICS

UH-60A USA S/N 84-23953

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG WHEEL HEIGHT (FT)	AIRCRAFT CONFIGURATION
⊡	17030	350.9	0.3 RT	1530	27.5	258	30	HELLFIRE
⊙	17080	351.1	0.3 RT	1420	27.0	258	30	HELLFIRE

NOTE: 1. VERTICAL LINES DENOTE CONTROL EXCURSIONS
2. PBA CENTERED AND LOCKED

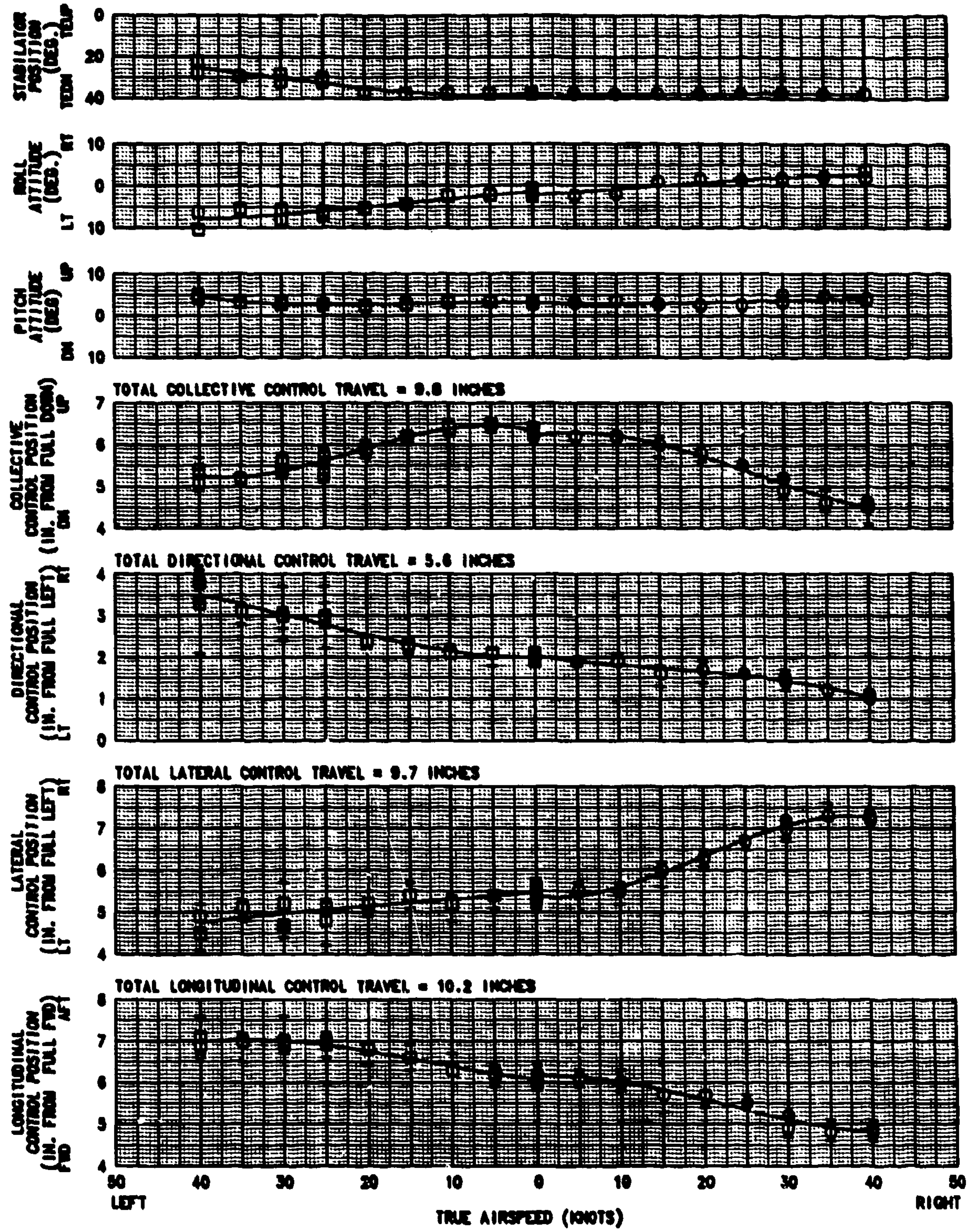


FIGURE 37

LOW SPEED 315 DEGREE AZIMUTH FLIGHT CHARACTERISTICS

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG WHEEL HEIGHT (FT)	AIRCRAFT CONFIGURATION
17070	351.1	0.3 RT	1430	27.0	258	30	HELLFIRE

NOTE: VERTICAL LINES DENOTE CONTROL EXCURSIONS

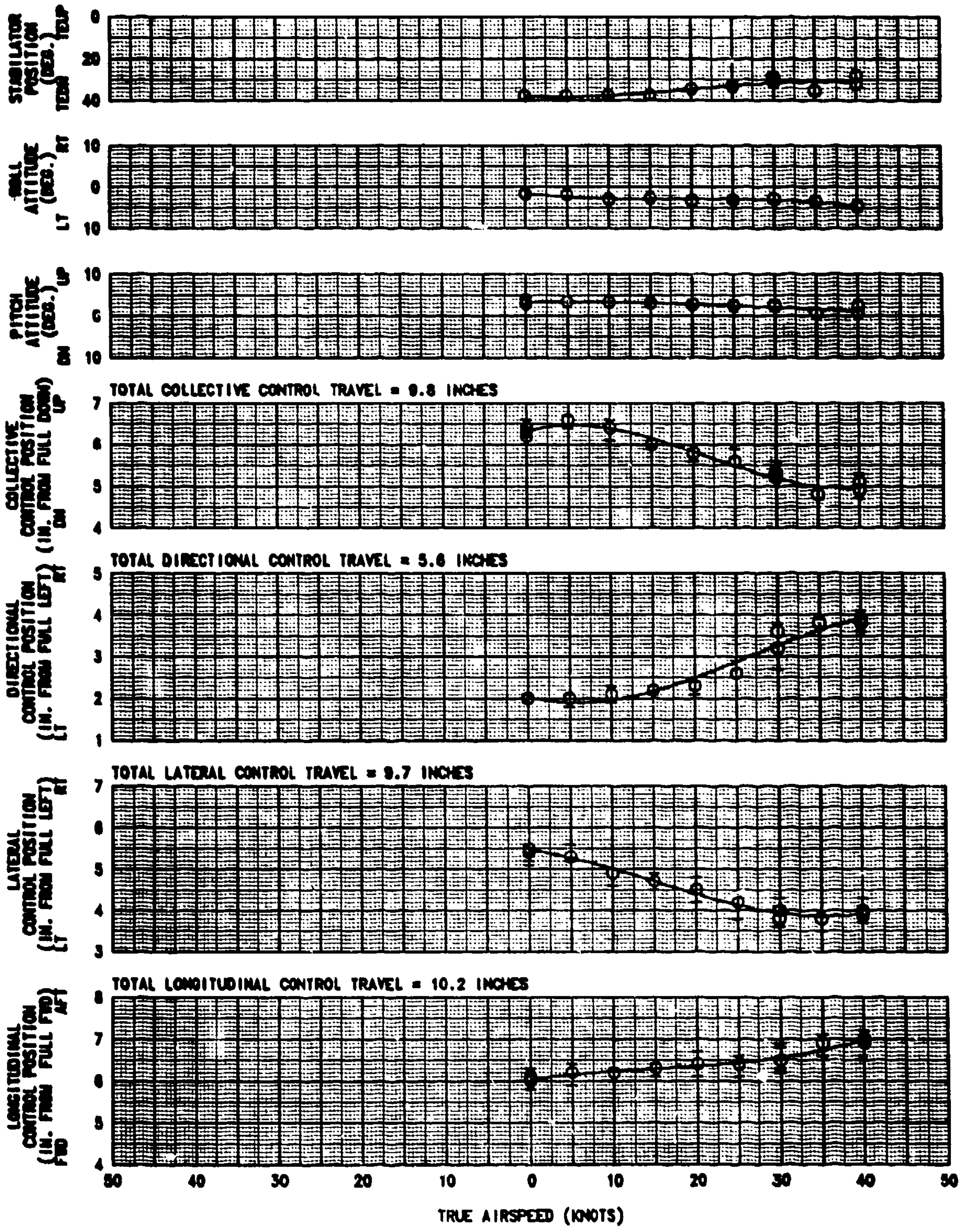


FIGURE 38

SIMULATED SINGLE ENGINE FAILURE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
17100	351.0	0.3 RT	7300	13.0	258	82	ON	HELLFIRE	LEVEL

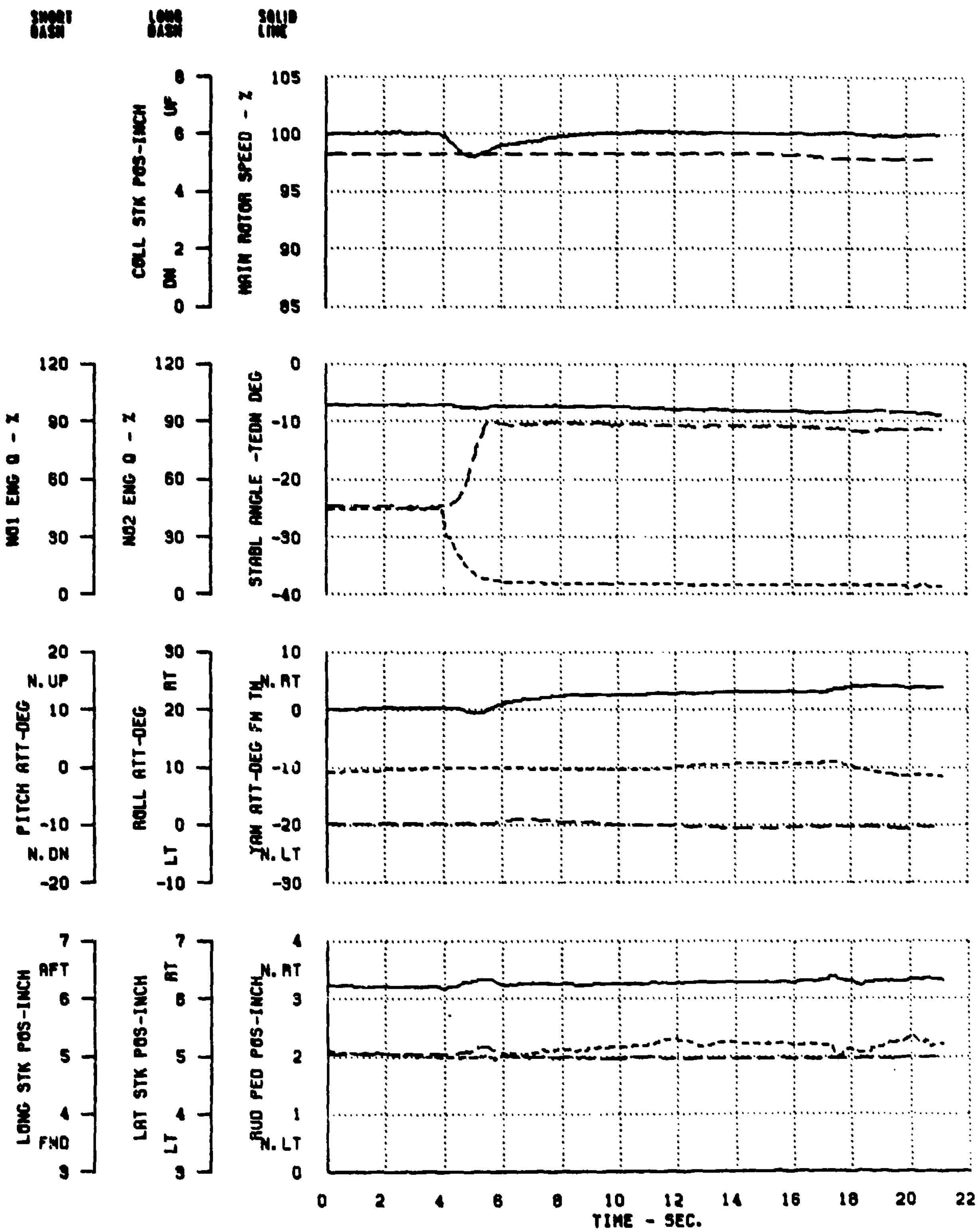


FIGURE 30
SIMULATED SINGLE ENGINE FAILURE
UH-60A USA S/N 84-23983

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
17020	330.4	0.3 RT	7800	12.0	258	132	ON	HELLFIRE	LEVEL

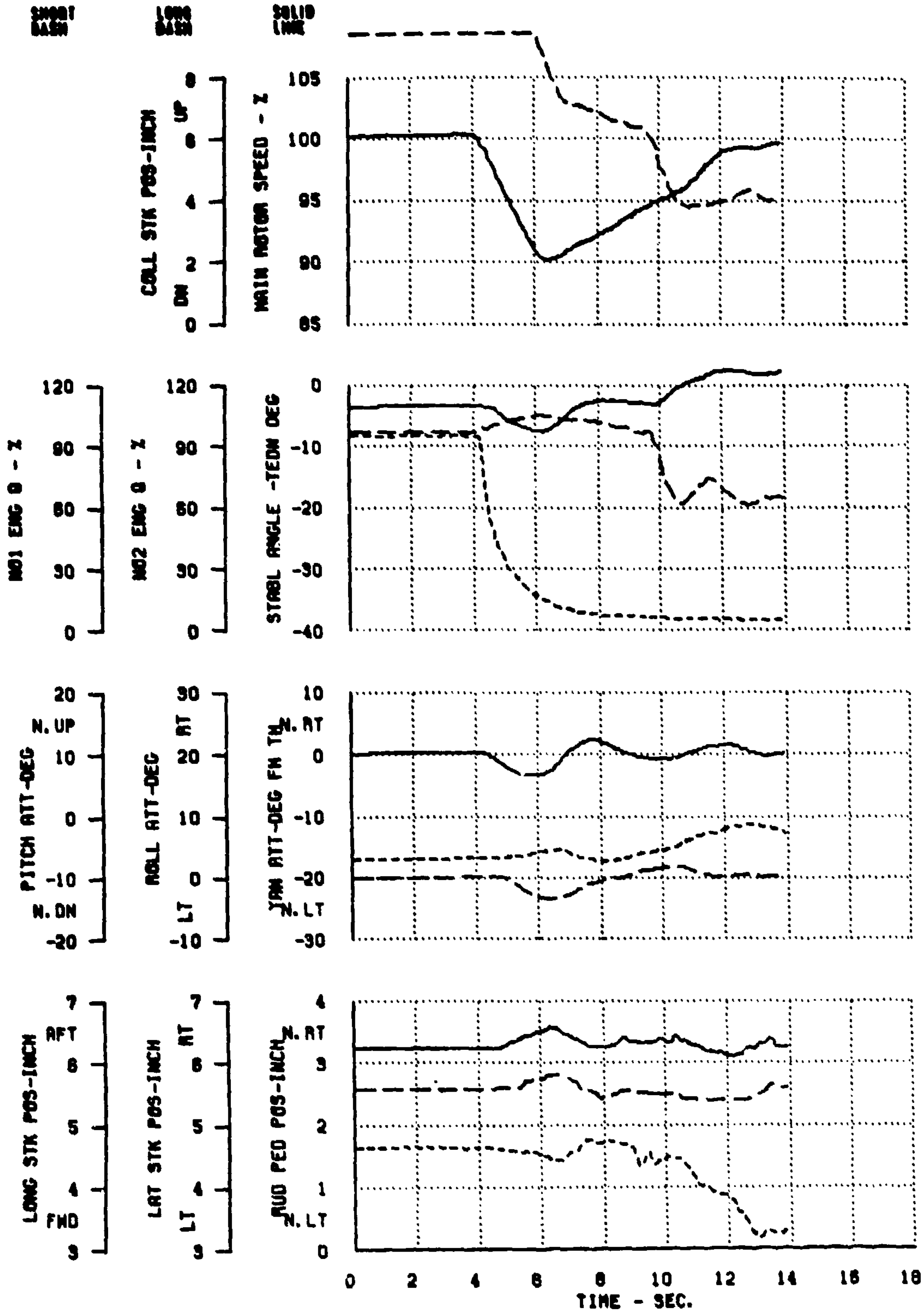


FIGURE 40
SIMULATED SINGLE ENGINE FAILURE
UH-60A USA S/N 84-23963

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	TRIM ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
16000	349.0	0.3 RT	7420	11.5	258	83	ON	HELLFIRE	IRP CLIMB

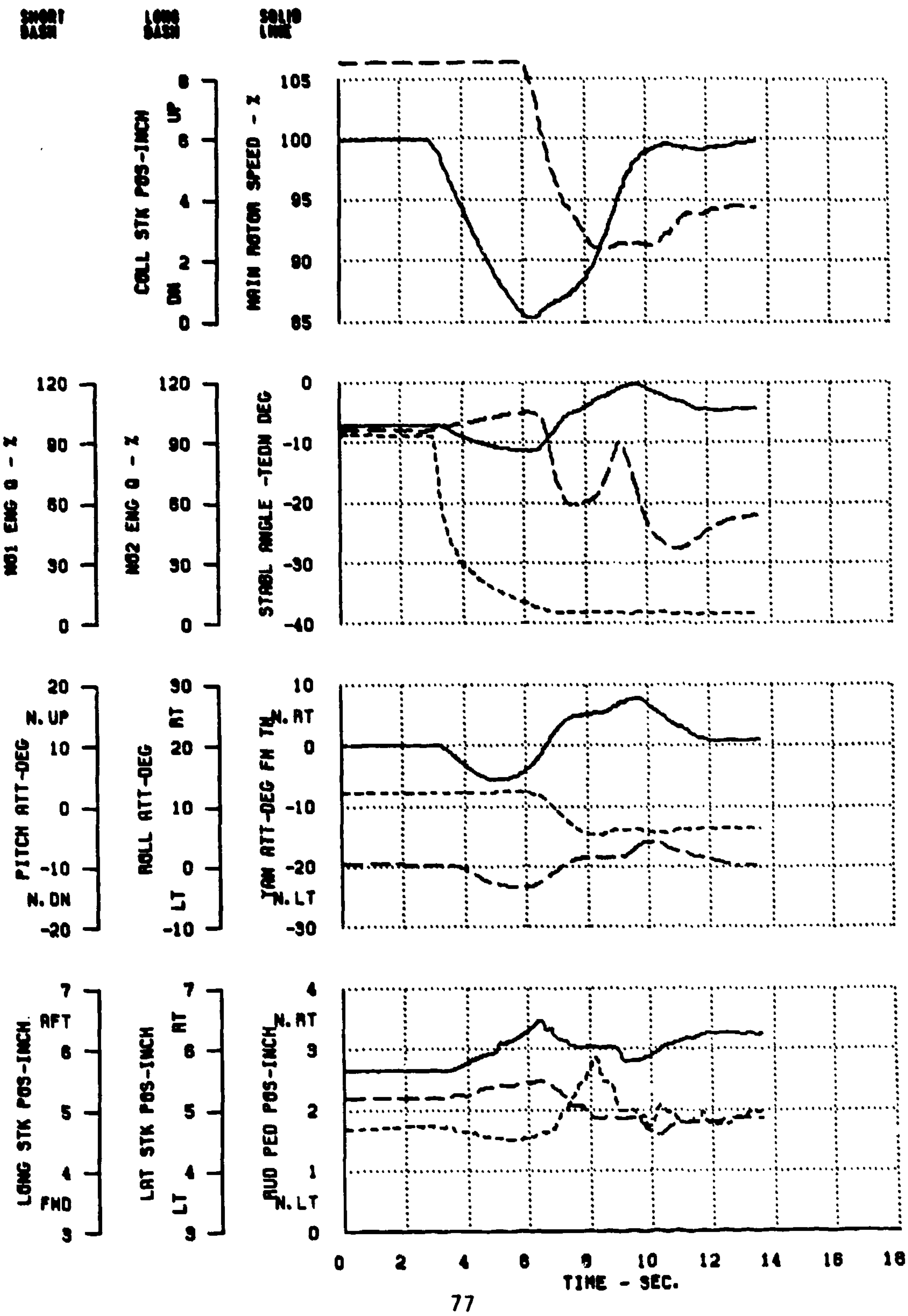


FIGURE 41
VIBRATION CHARACTERISTICS
PILOT SEAT
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
17010	356.1	0.3 RT	5290	17.5	259	0.007006

NOTE: 1. ESSS ONLY CONFIGURATION
2. LEVEL FLIGHT

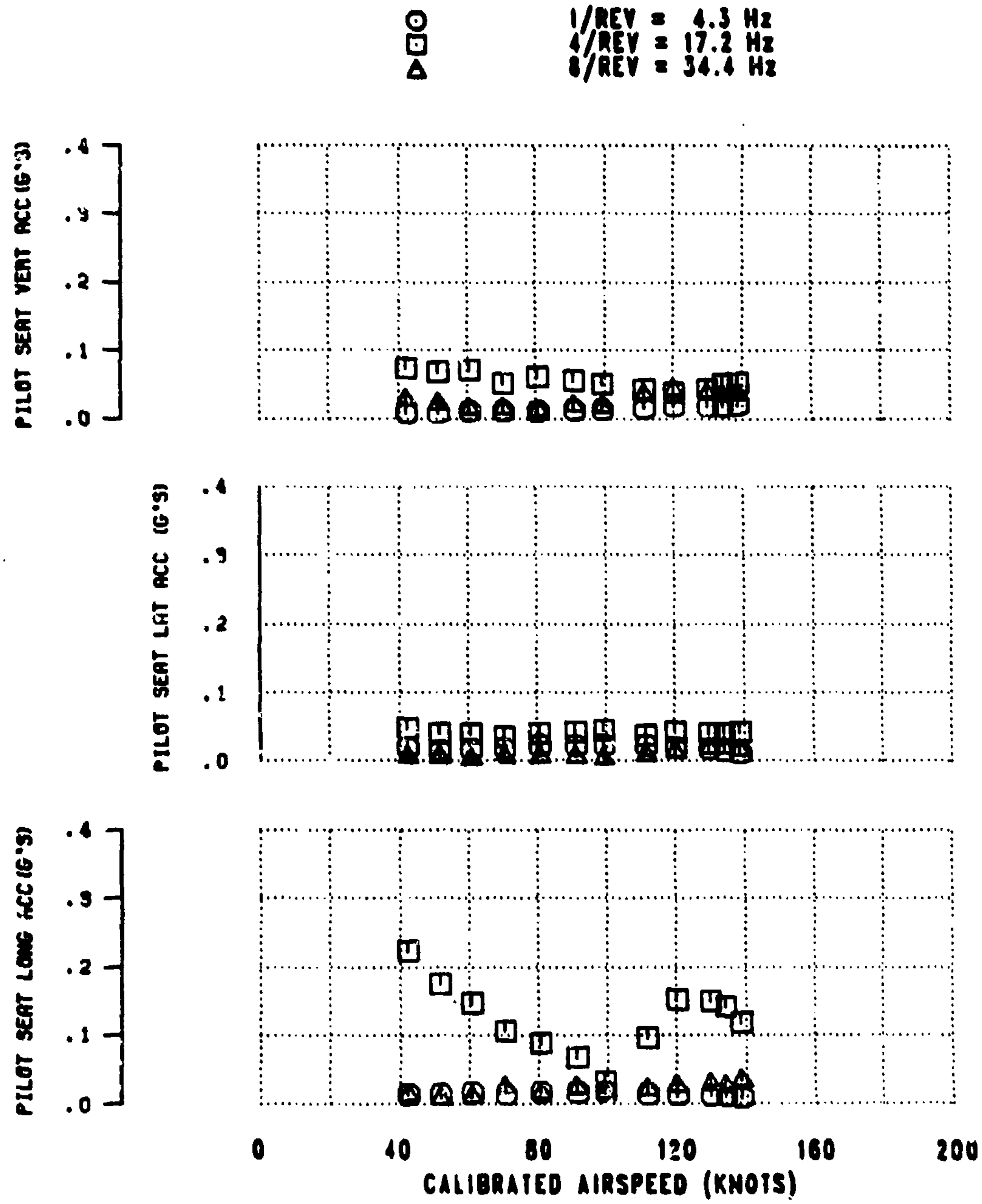


FIGURE 42
VIBRATION CHARACTERISTICS
PILOT SEAT
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
16930	350.0	0.3 RT	5250	16.0	258	0.006991

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT

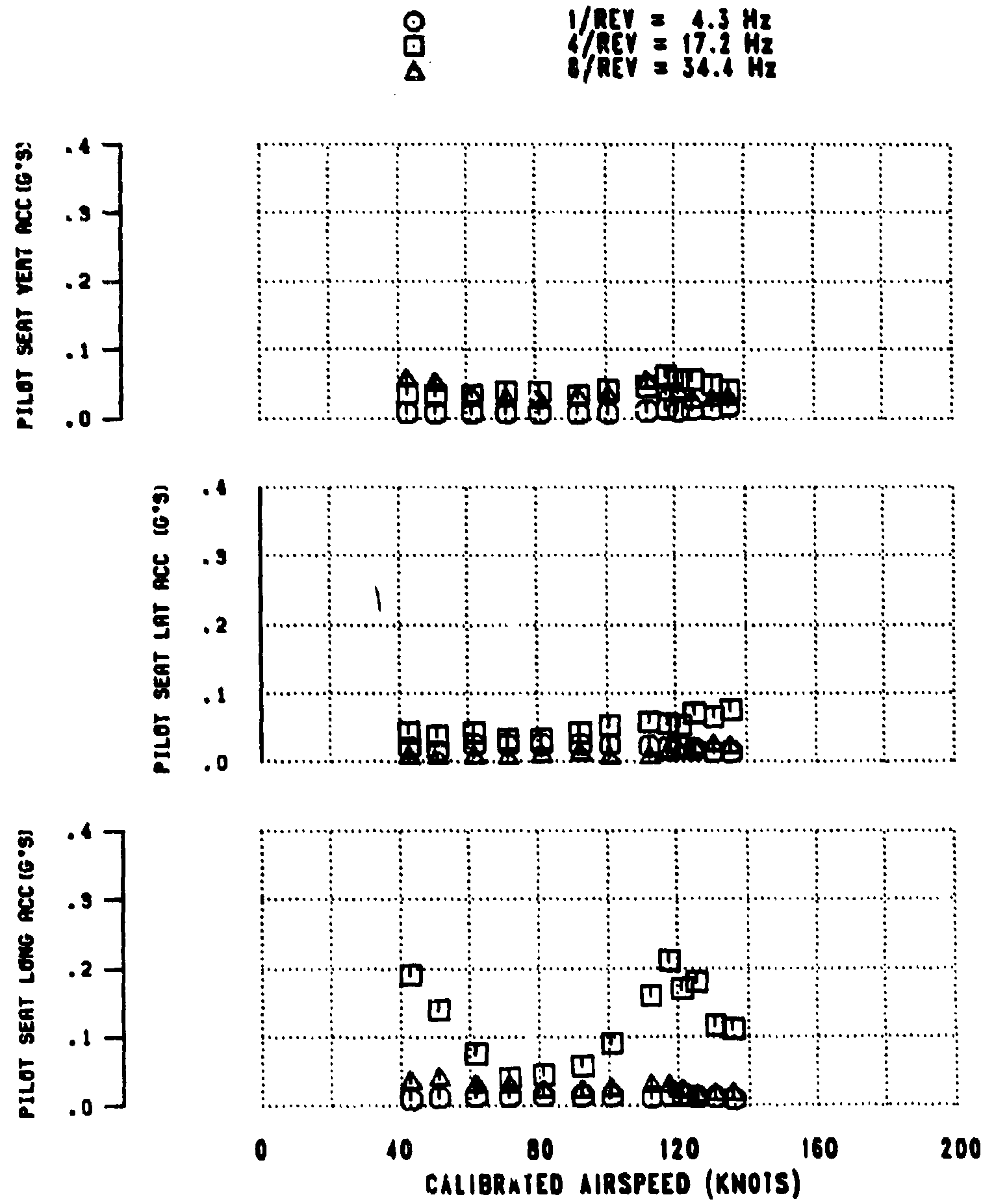


FIGURE 43

VIBRATION CHARACTERISTICS

PILOT SEAT

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
16880	349.5	0.3 RT	12350	6.0	254	0.008978

NOTE: 1. ESSS ONLY CONFIGURATION
2. LEVEL FLIGHT

○ 1/REV = 4.3 Hz
□ 4/REV = 17.2 Hz
△ 8/REV = 34.4 Hz

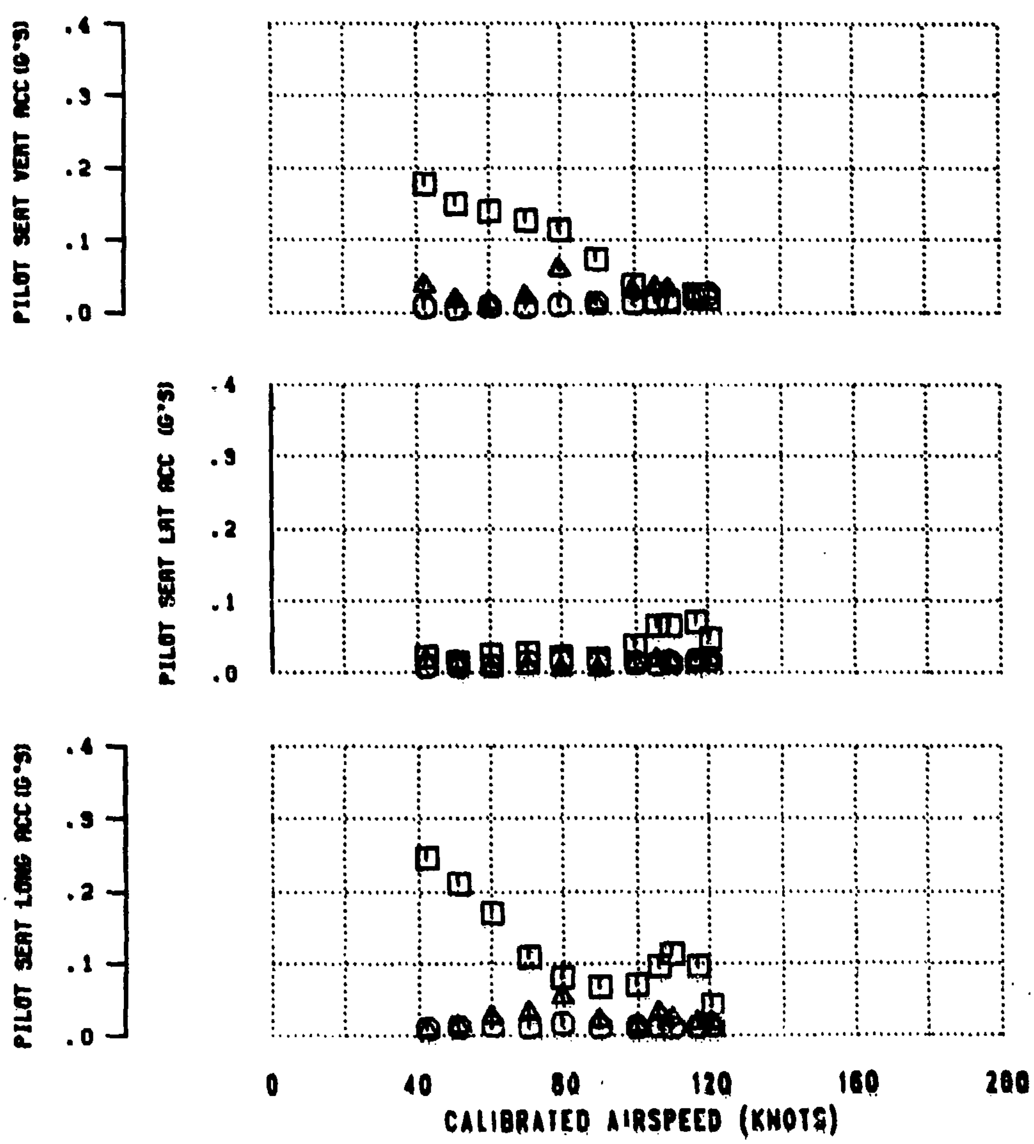


FIGURE 44
VIBRATION CHARACTERISTICS
PILOT SEAT
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
16980	350.1	0.3 RT	12190	6.5	254	0.009016

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT

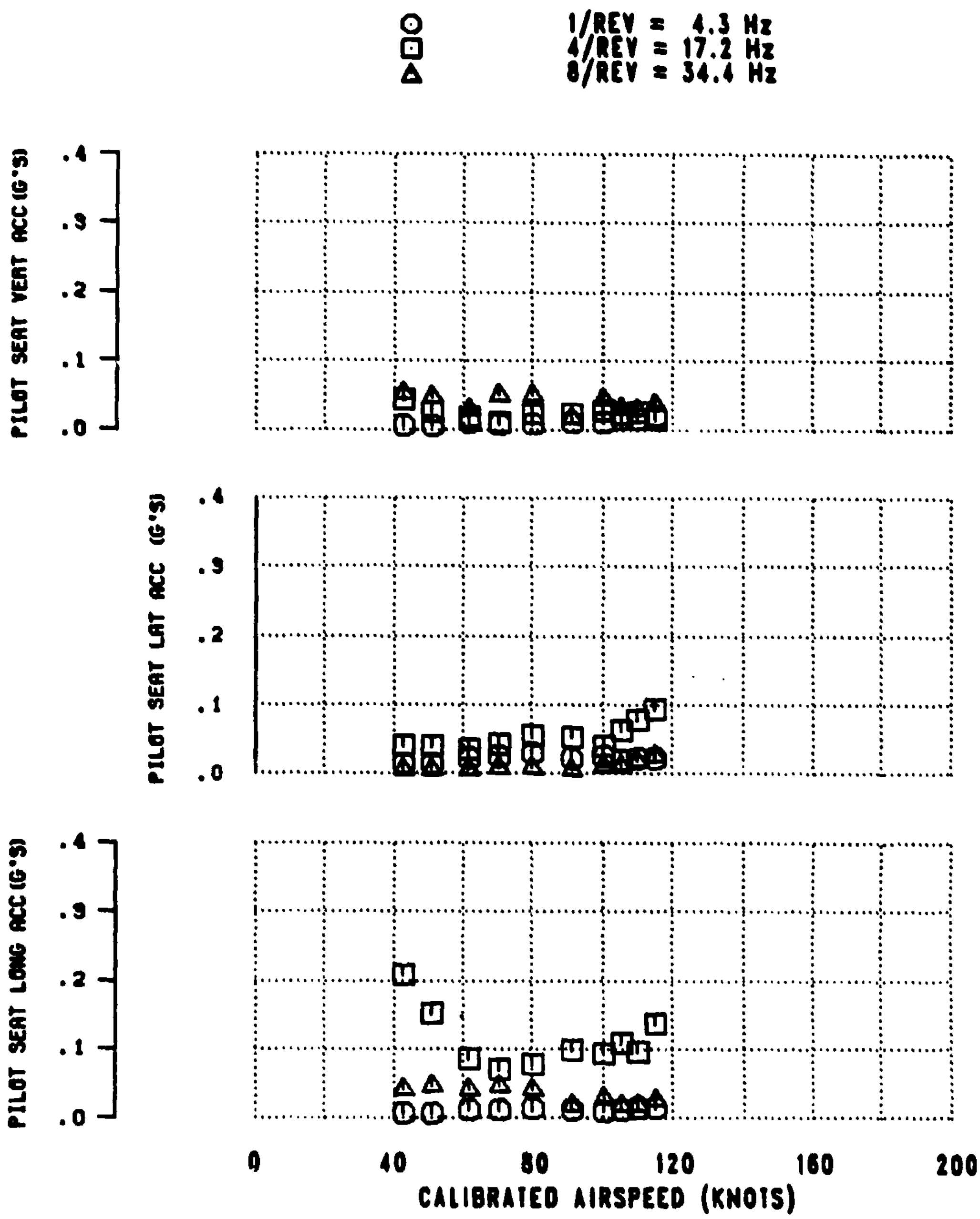


FIGURE 45
VIBRATION CHARACTERISTICS
CABIN FLOOR
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
17010	350.1	0.3 RT	5290	17.5	258	0.007006

NOTE: 1. ESSS ONLY CONFIGURATION
2. LEVEL FLIGHT

○ 1/REV = 4.3 Hz
□ 4/REV = 17.2 Hz
△ 8/REV = 34.4 Hz

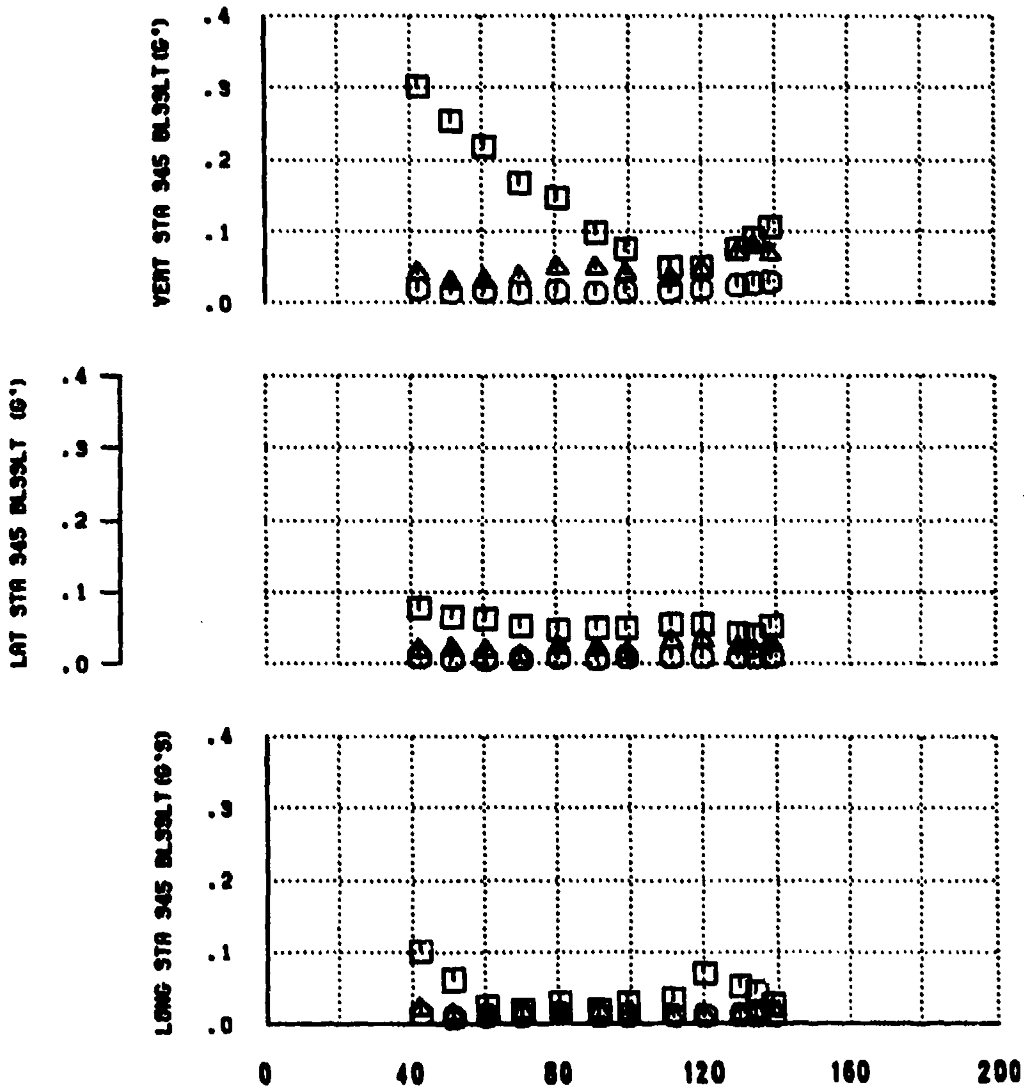


FIGURE 48

VIBRATION CHARACTERISTICS

CABIN FLOOR

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
16950	350.0	0.3 RT	5250	16.0	258	0.006991

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT

○ 1/REV = 4.3 Hz
□ 4/REV = 17.2 Hz
△ 8/REV = 34.4 Hz

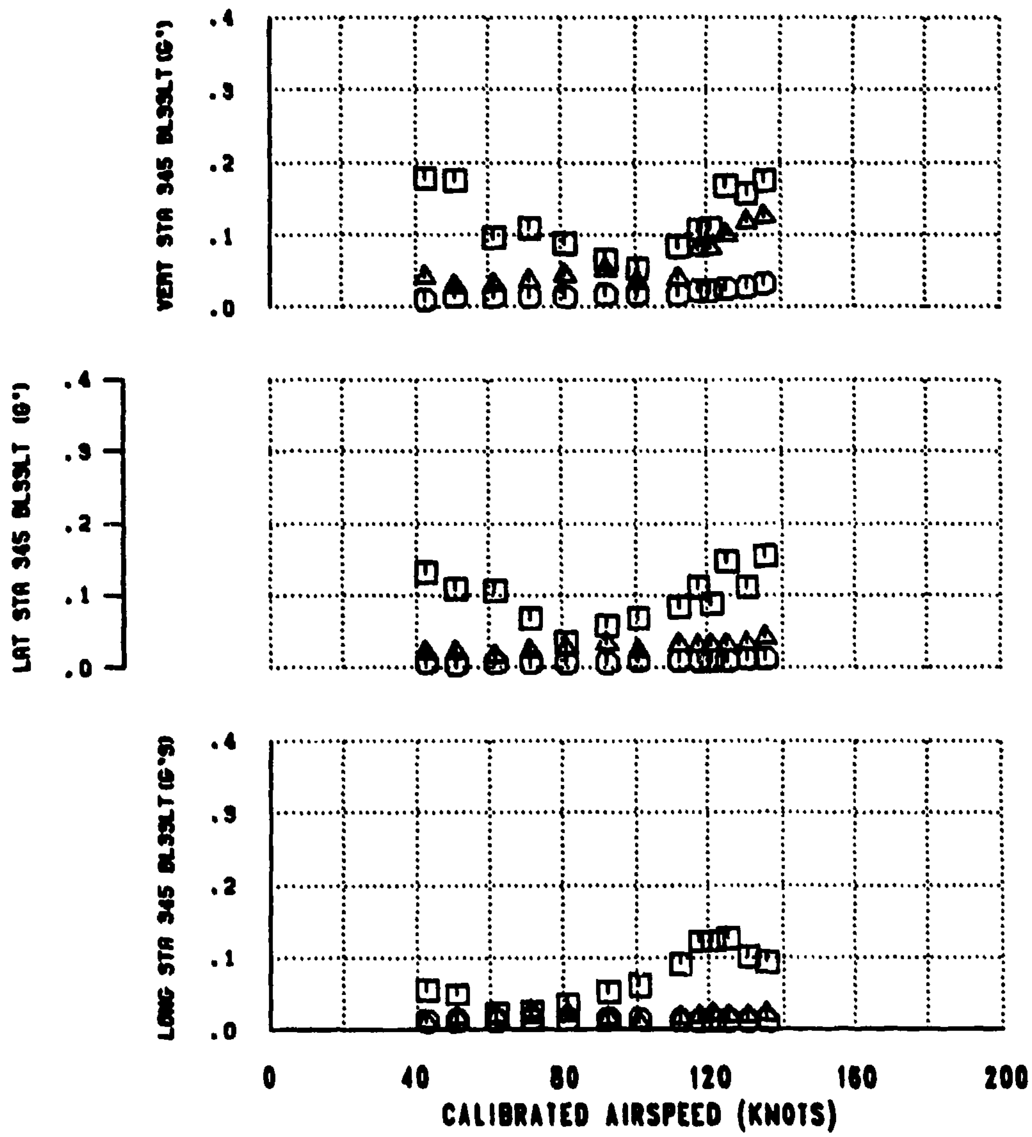


FIGURE 47
VIBRATION CHARACTERISTICS
CABIN FLOOR
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
16880	349.5	0.3 RT	12350	6.0	254	0.008978

NOTE: 1. ESSS ONLY CONFIGURATION
2. LEVEL FLIGHT

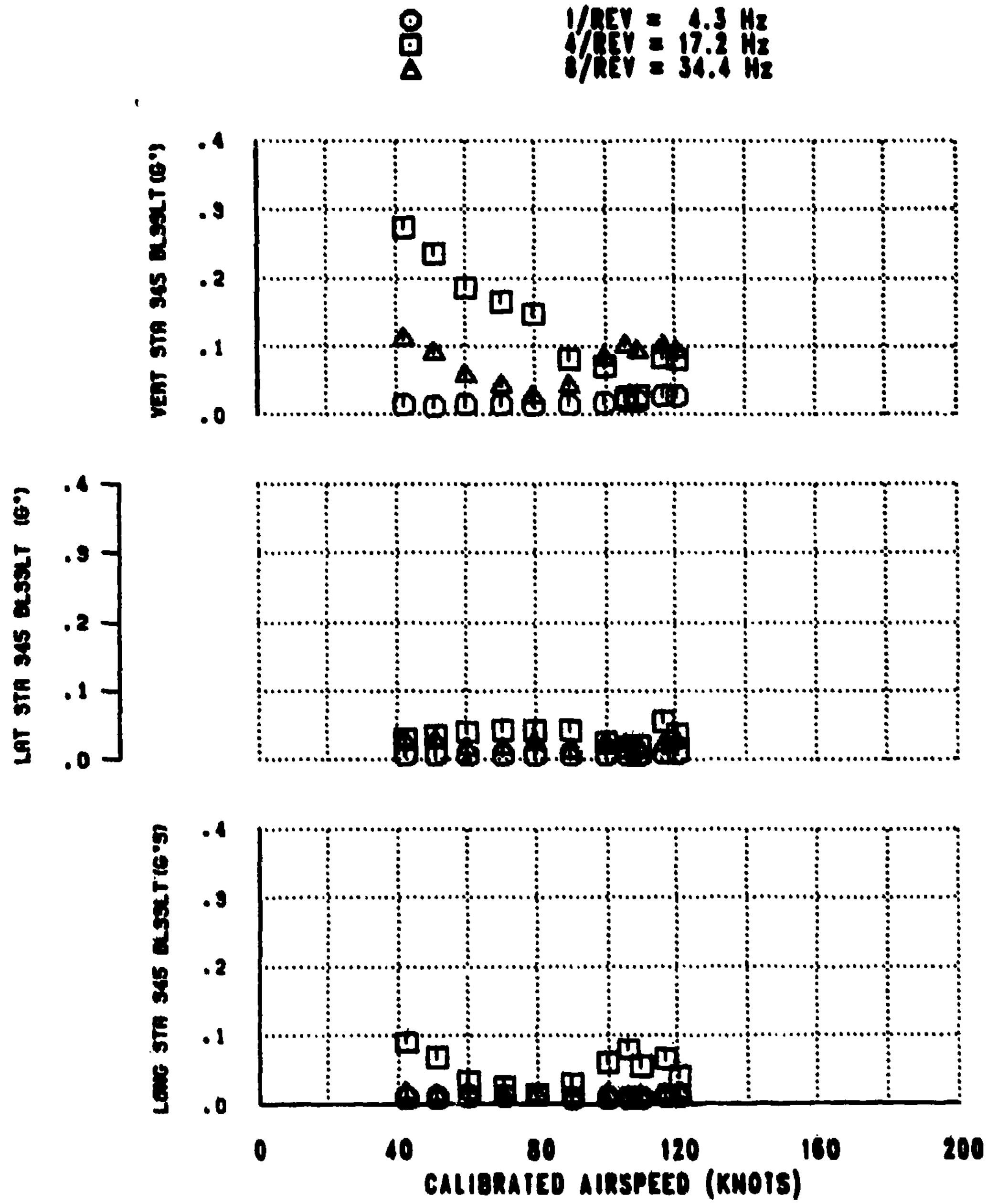


FIGURE 48
VIBRATION CHARACTERISTICS
CABIN FLOOR
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFFICIENT
16980	350.1	0.3 RT	12190	6.5	254	0.009016

NOTE: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT

○ 1/REV = 4.3 Hz
□ 4/REV = 17.2 Hz
△ 8/REV = 34.4 Hz

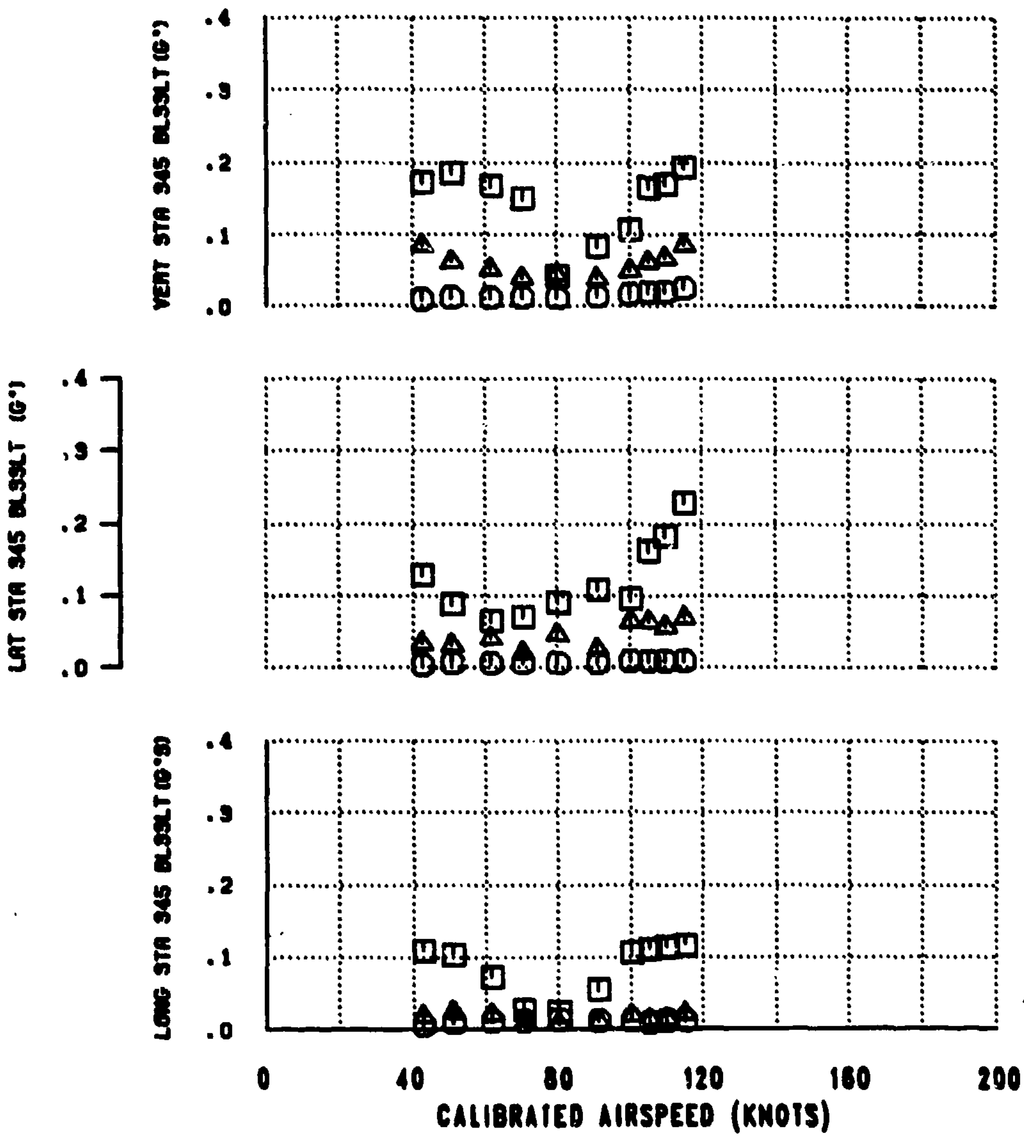


FIGURE 49

SHIP AIRSPEED CALIBRATION

UH-60A USA S/N 84-23953

SYM	AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	TEST METHOD
⊙	15270	350.6	0.2 RT	3350	13.5	TRAILING BOMB
△	18600	350.6	0.2 RT	6200	17.5	TRAILING BOMB
⊡	17500	350.0	0.2 RT	-10	16.0	GRND SPD CRSE

NOTES:
1. NORMAL UTILITY CONFIGURATION
2. LEVEL FLIGHT
3. BALL CENTERED TRIM CONDITION
4. MAIN ROTOR SPEED=258 RPM

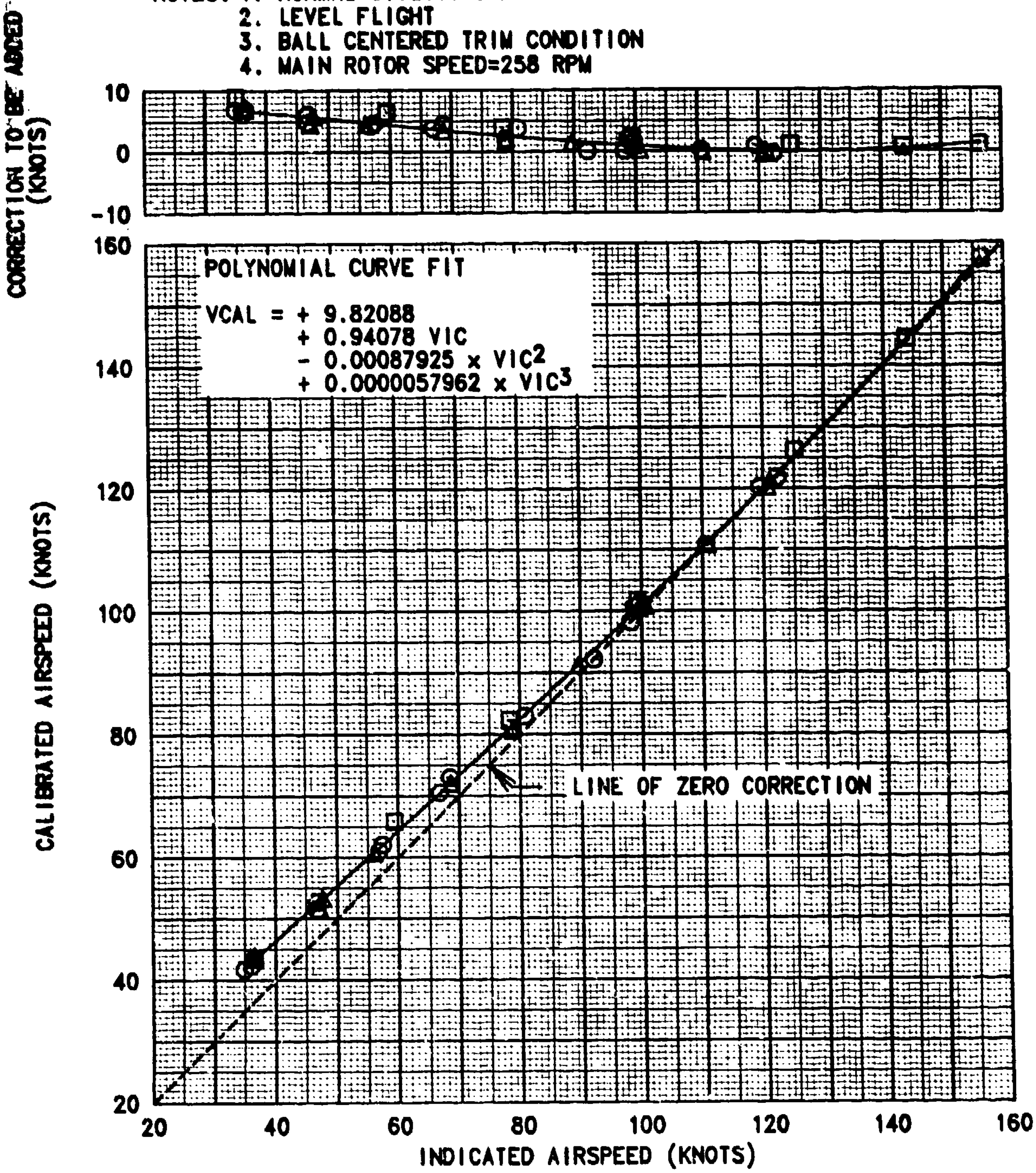


FIGURE 50

SHIP AIRSPEED CALIBRATION

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	TEST METHOD
17040	350.2	0.2 RT	6460	15.0	TRAILING BOMB

NOTES: 1. ESSS ONLY CONFIGURATION
2. LEVEL FLIGHT
3. BALL CENTERED TRIM CONDITION
4. MAIN ROTOR SPEED=258 RPM

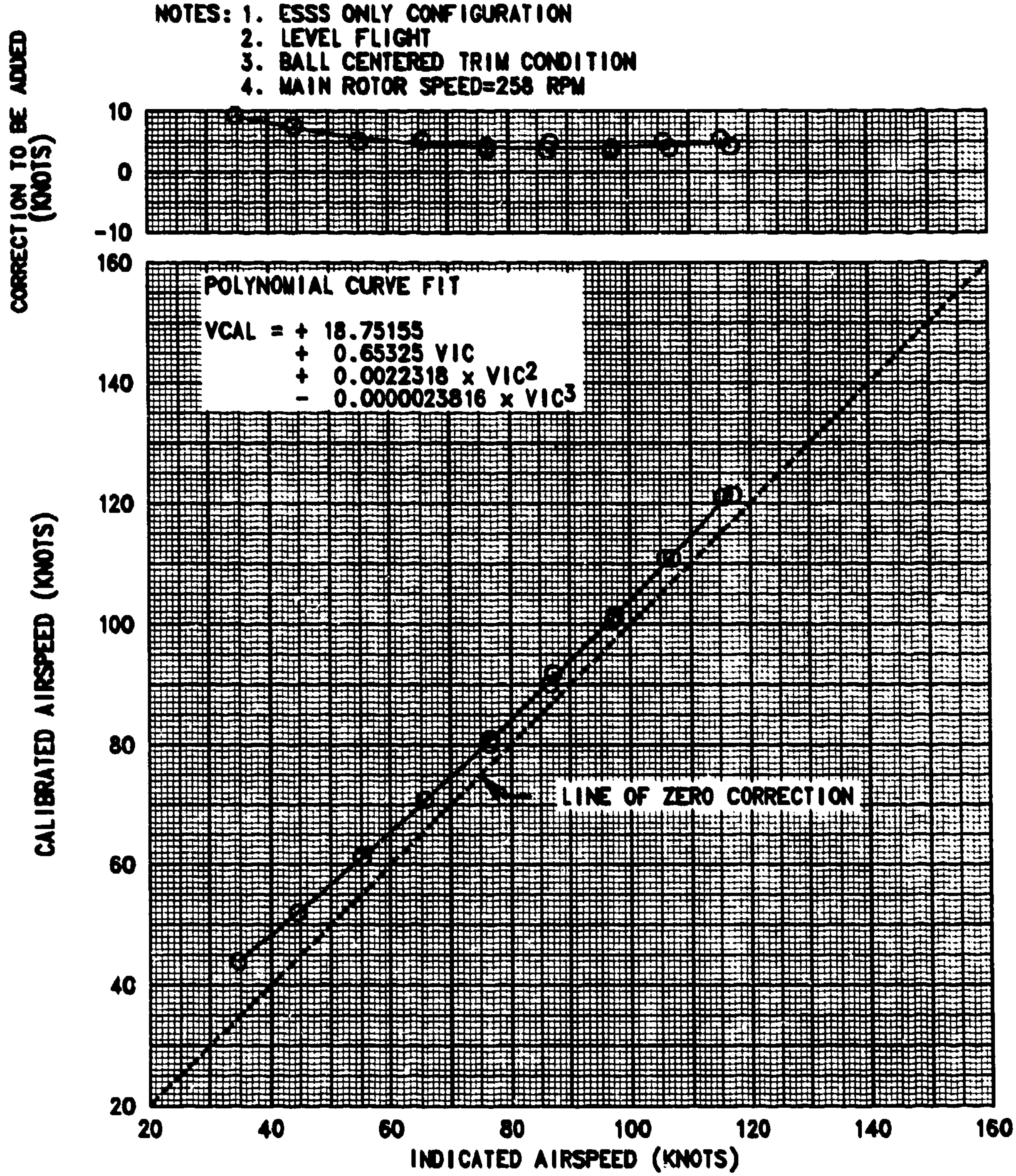
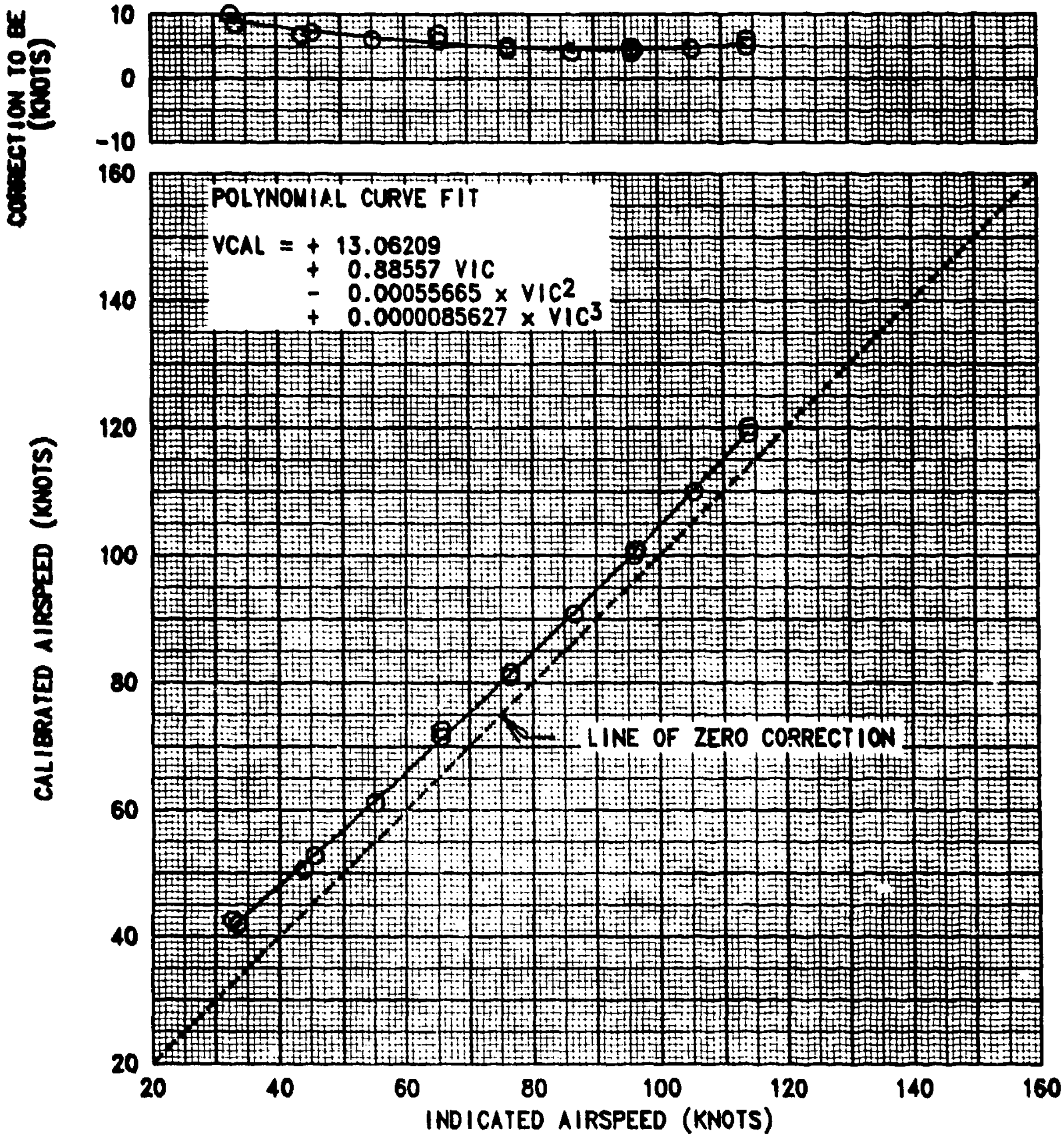


FIGURE 51
SHIP AIRSPEED CALIBRATION
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	TEST METHOD
16880	349.7	0.2 RT	6090	13.0	TRAILING BOMB

NOTES: 1. ESSS WITH HELLFIRE (4 HMMS) CONFIGURATION
2. LEVEL FLIGHT
3. BALL CENTERED TRIM CONDITION
4. MAIN ROTOR SPEED=258 RPM



APPENDIX F. PHOTOGRAPHS

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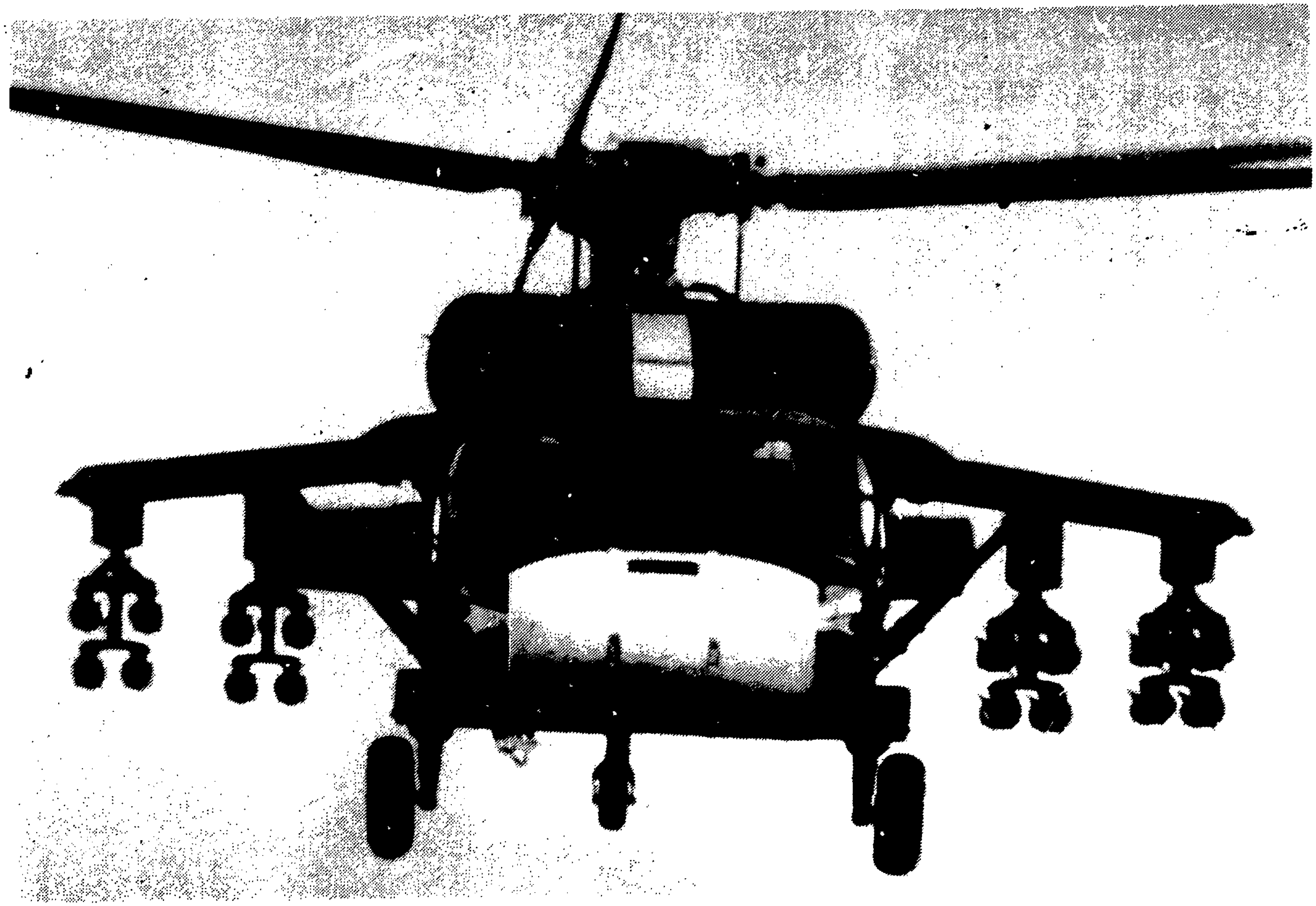

Photo 1. Front View - UH-60A Helicopter with 4 HMMS Installed

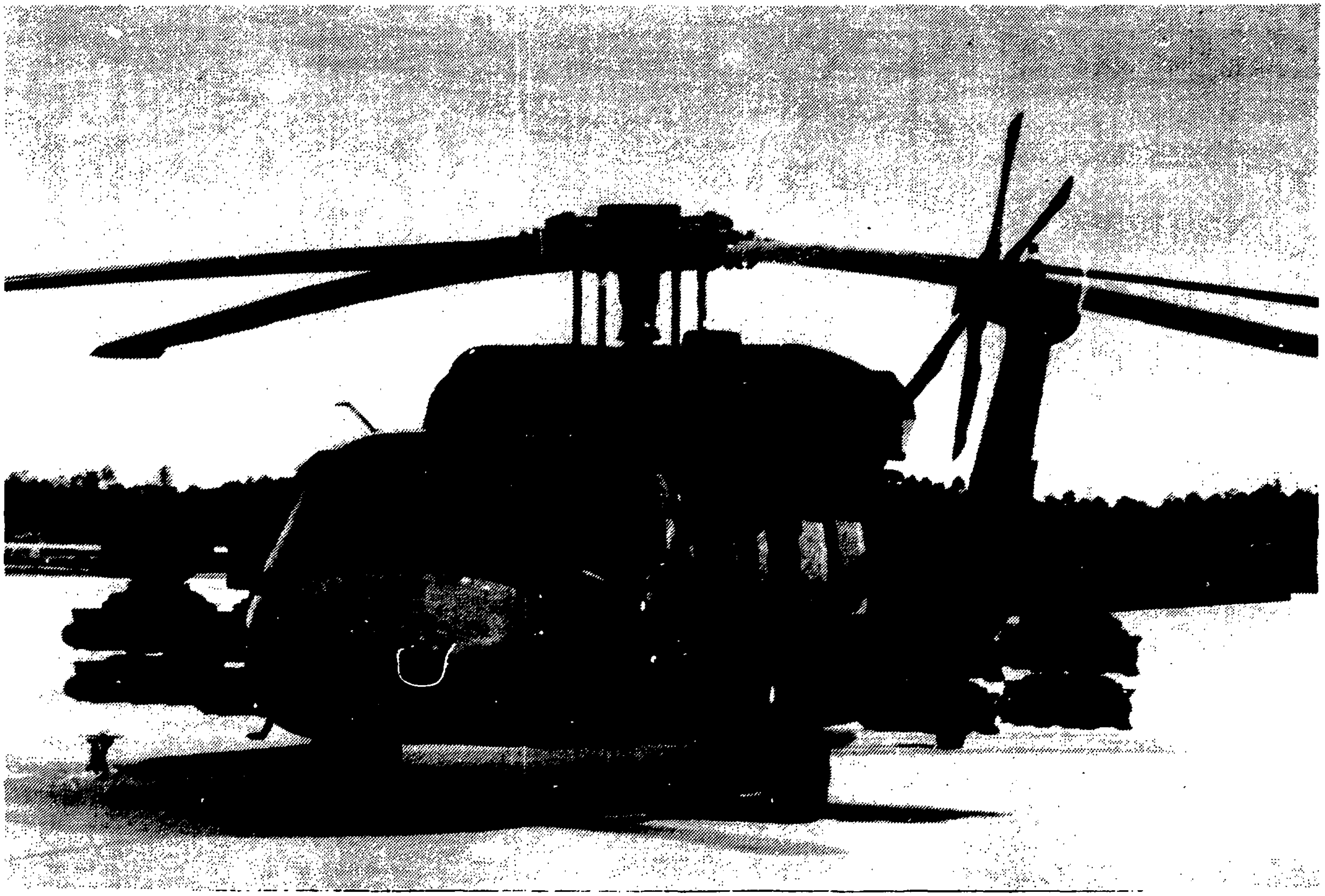

Photo 2. Left Quarter View - UH-60A Helicopter with 4 HMMS Installed

Photo 3. Left Side View - UH-60A Helicopter with 4 HMMS Installed

Photo 4. Right Rear Quarter View - UH-60A Helicopter with 4 HMMS Installed

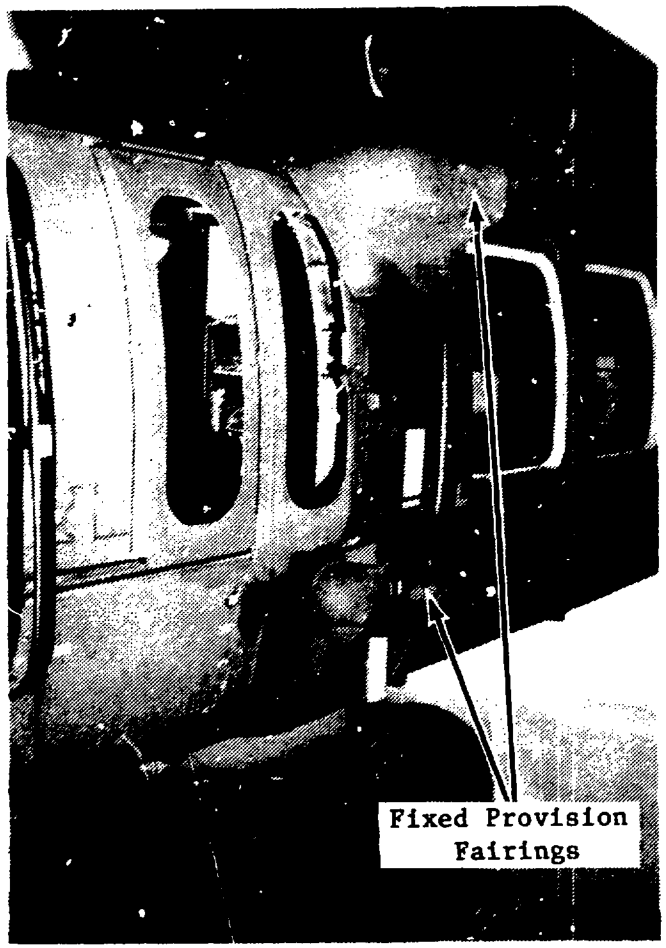

Photo 5. Fixed Provision Fairings Installed

Photo 6. Fixed Provision Mounting Points with Fairings Removed

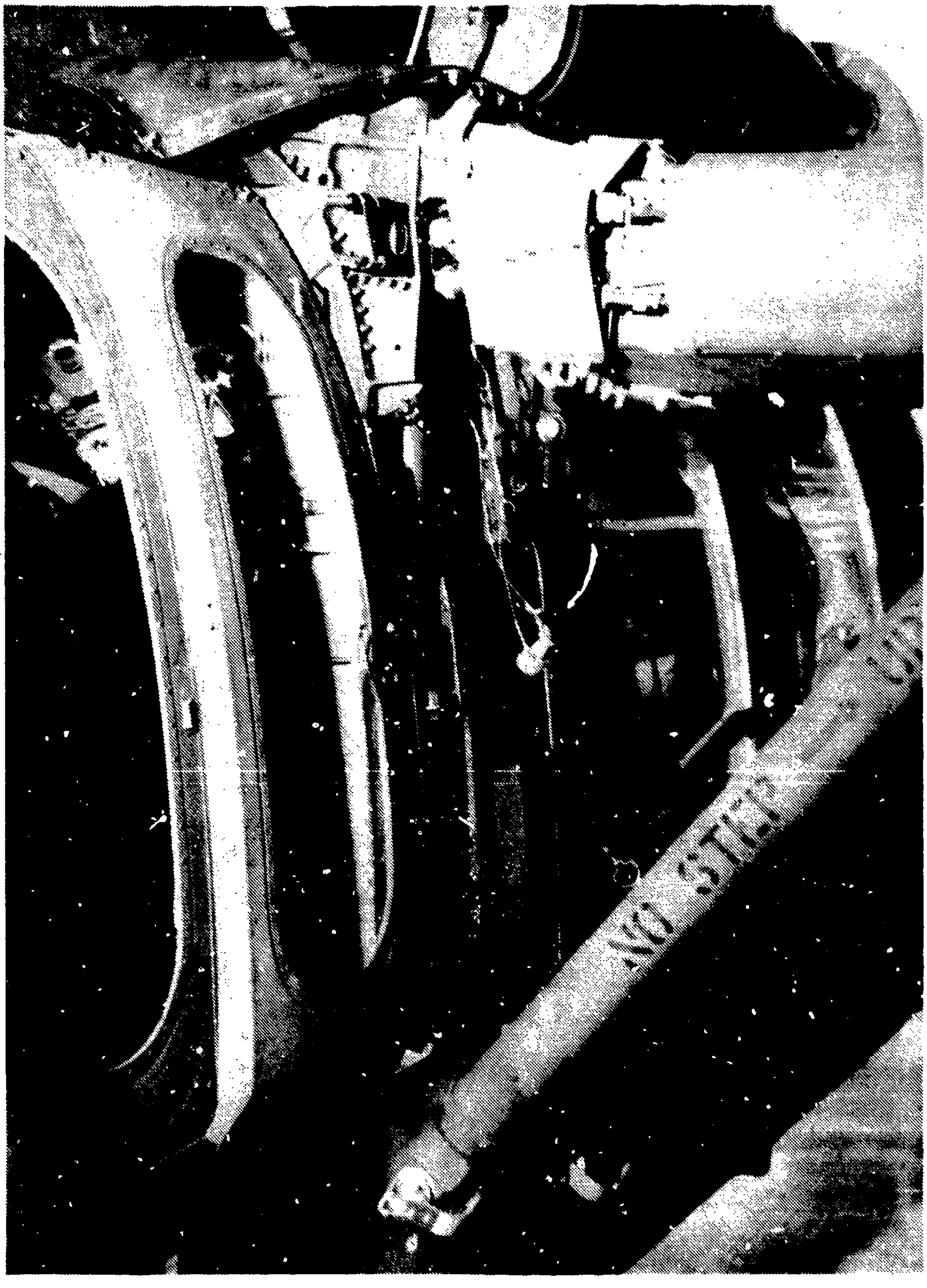

Photo 7. ESSS Installation onto Fixed Provision Mounting Points

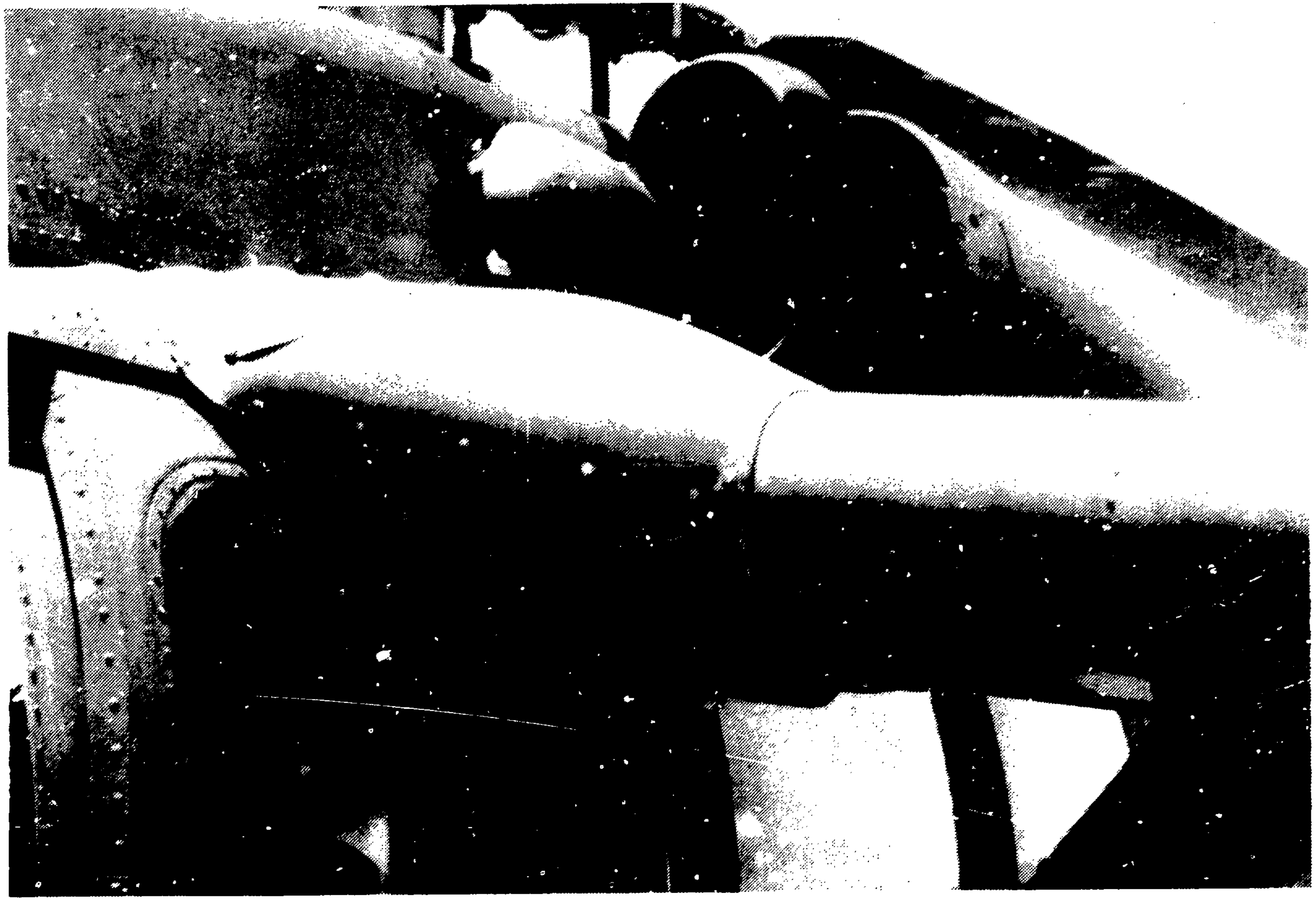

Photo 8. ESSS Prototype Fairing Installed

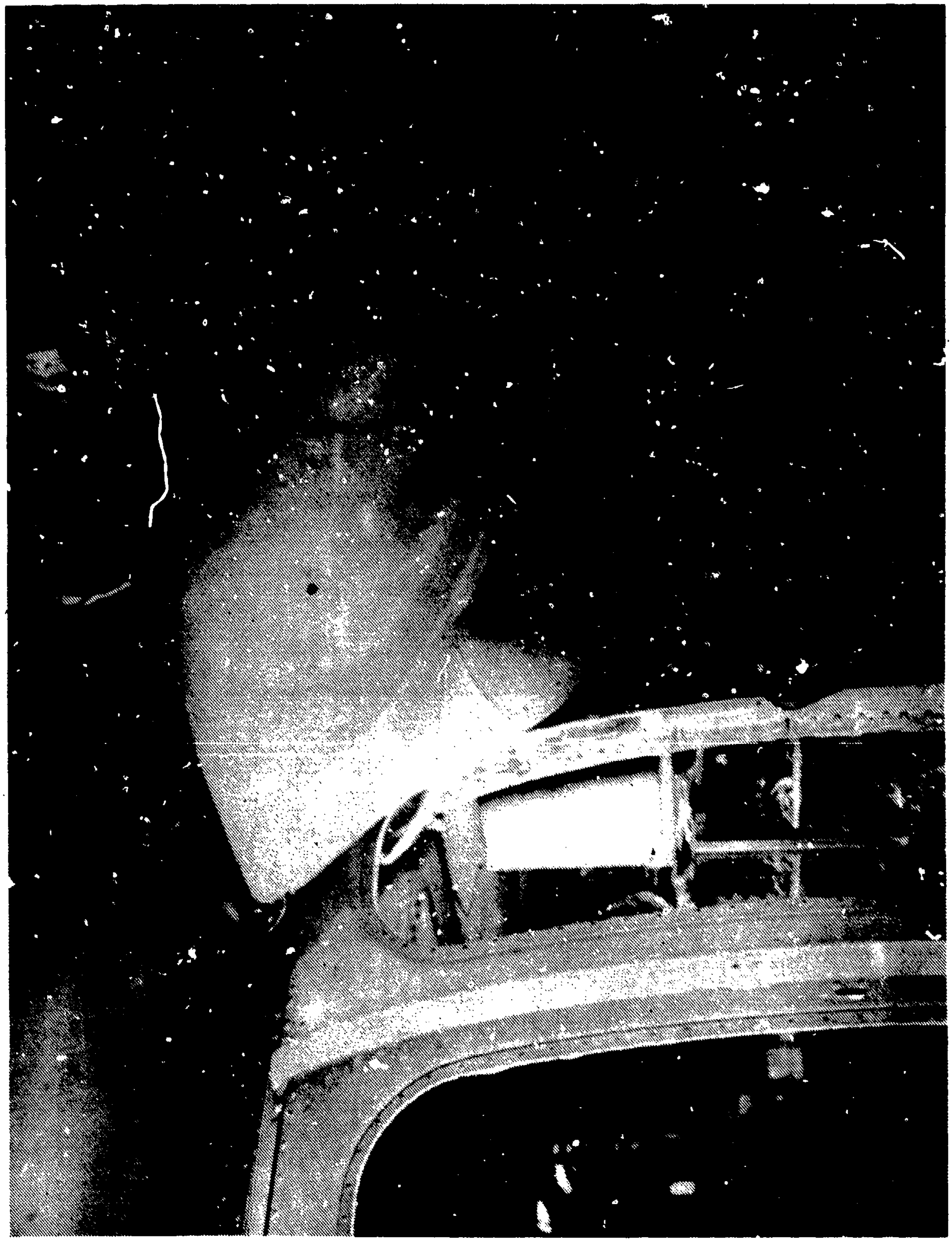

Photo 9. ESSS Production Fairing Installed

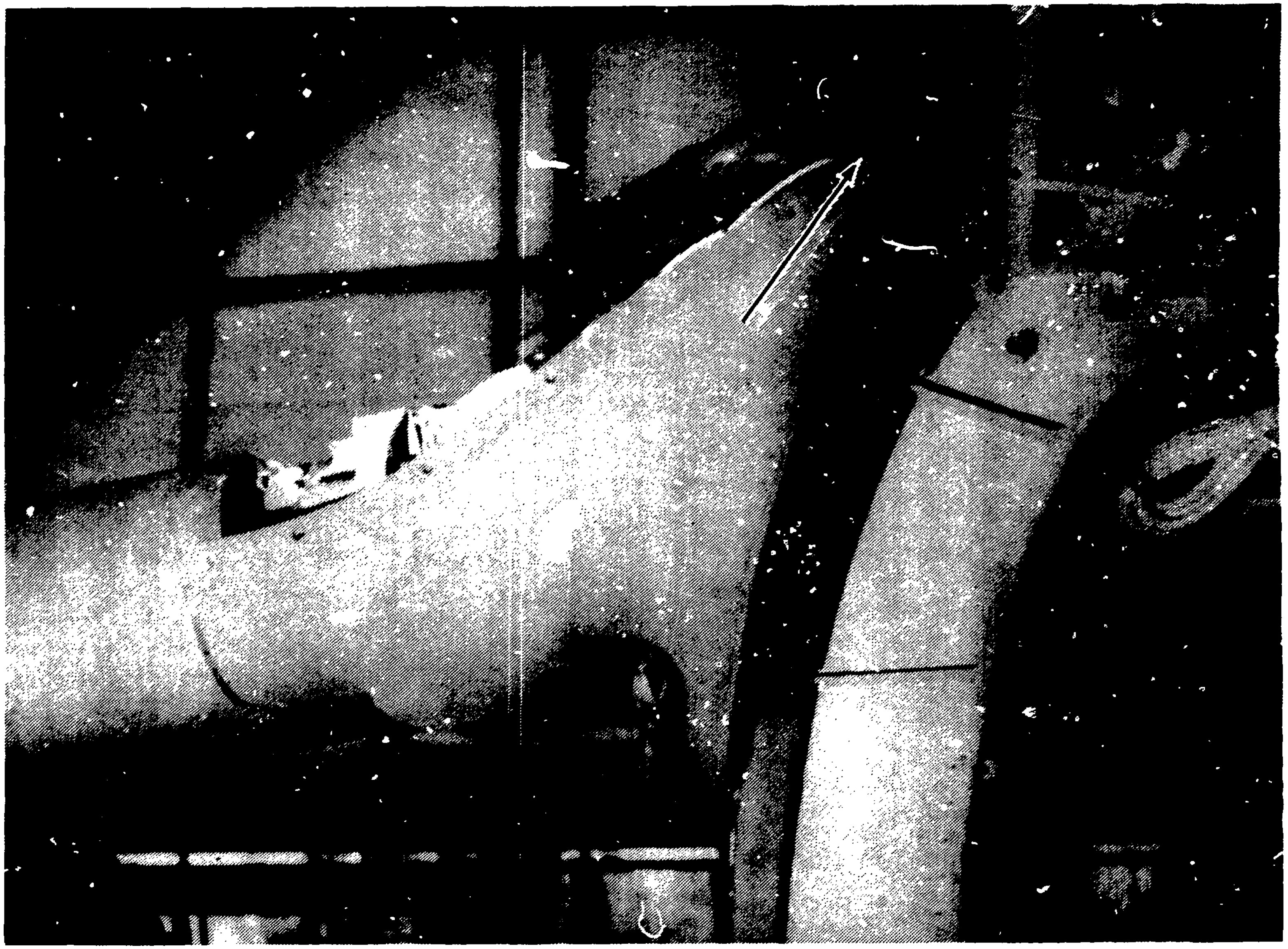

Photo 10. Production Fairing Interference with Sliding Cargo Door Seal

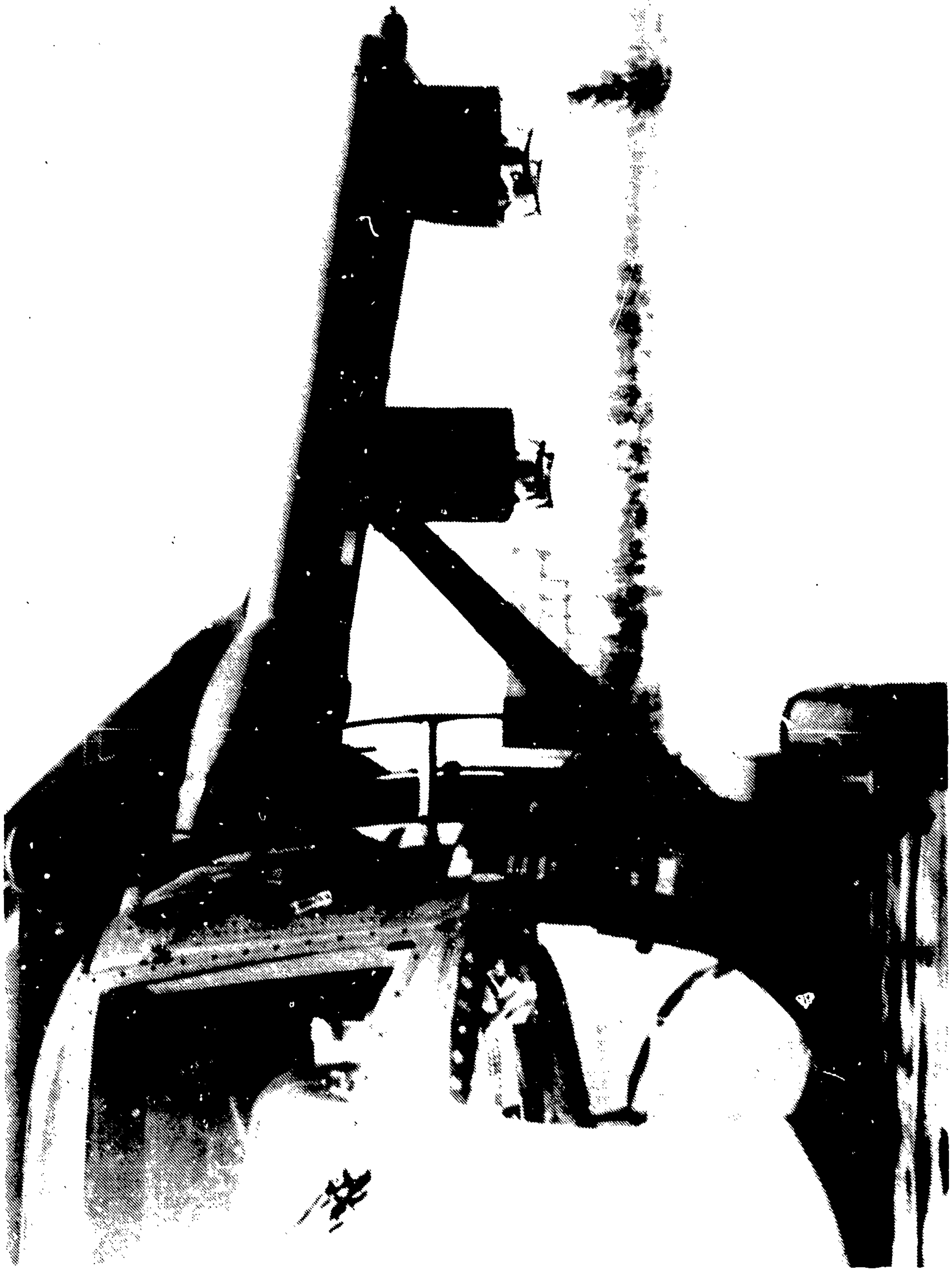

Photo 11. ESSS Installation

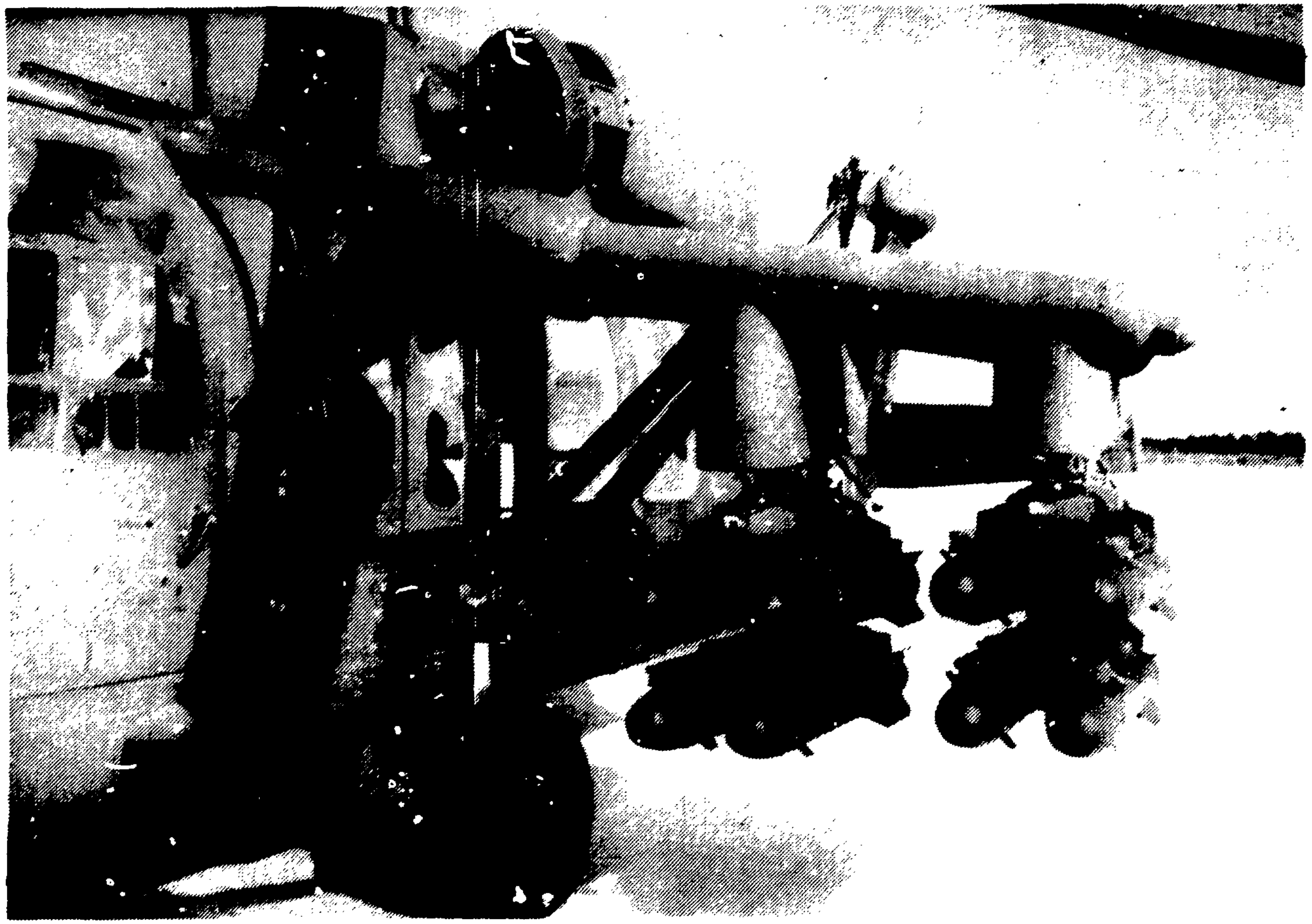

Photo 12. HELLFIRE Installation onto ESSS

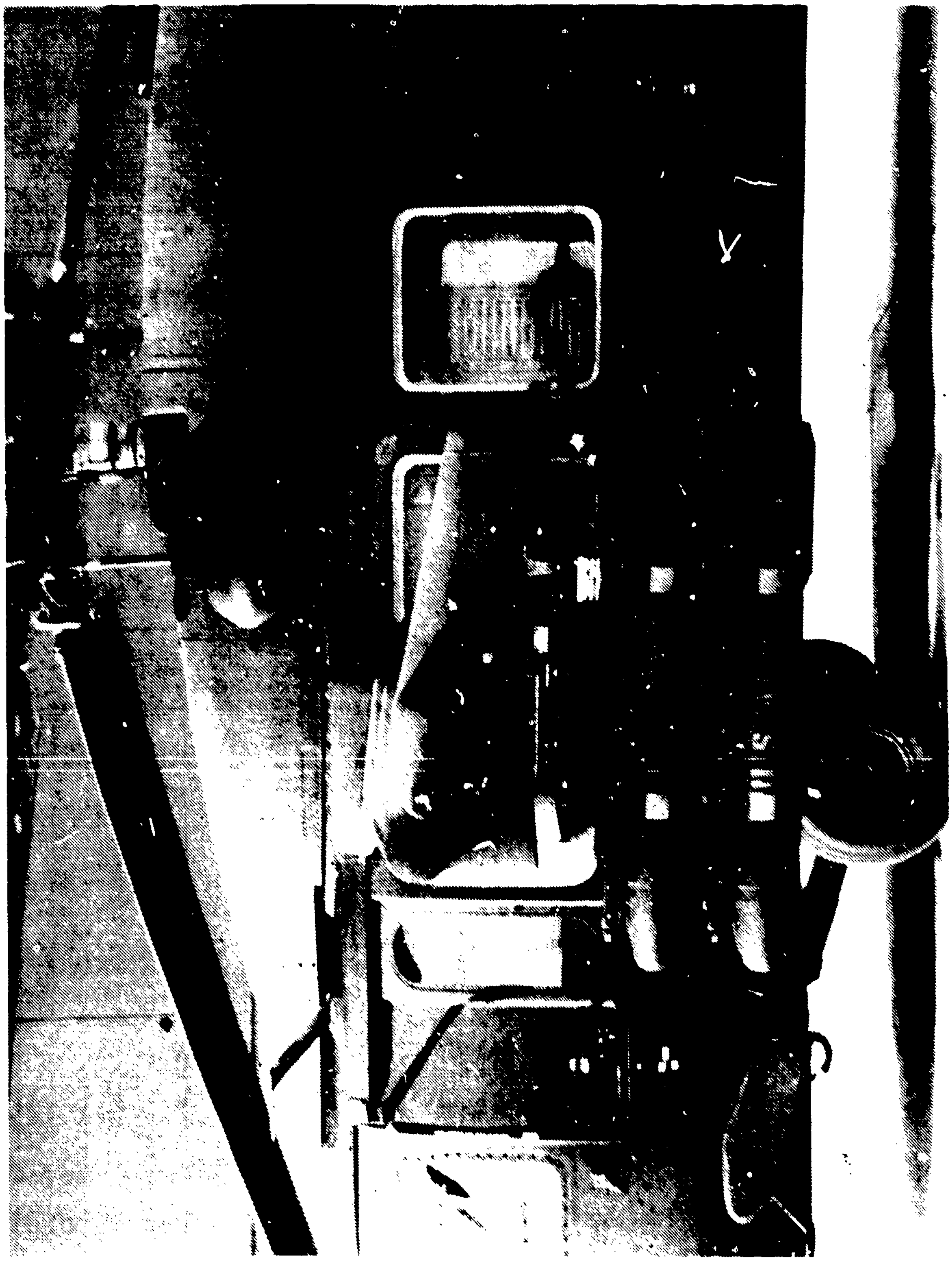

Photo 13. Side View - HELLFIRE Installation

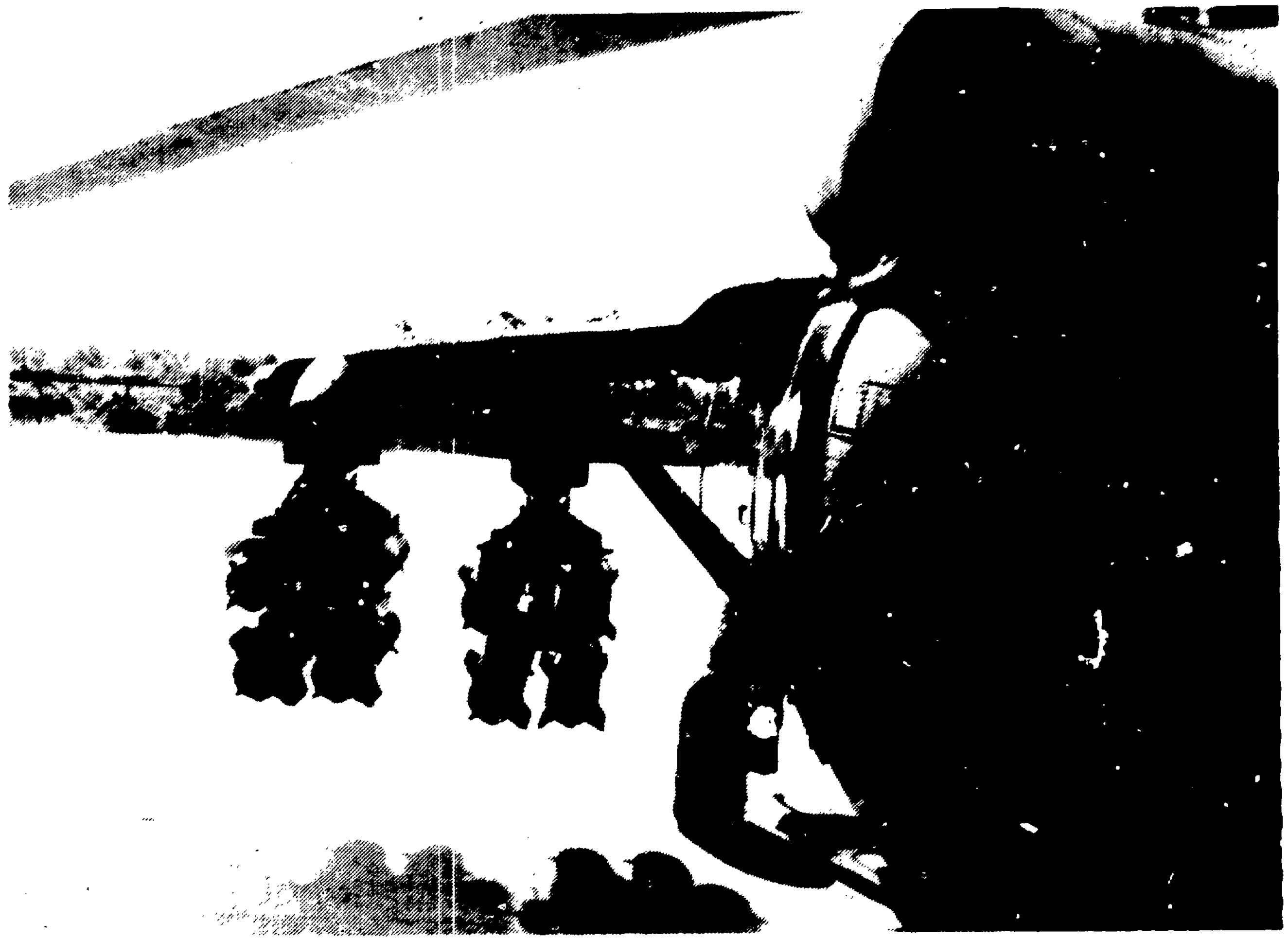

Photo 14. Rear View - HELLFIRE Installation

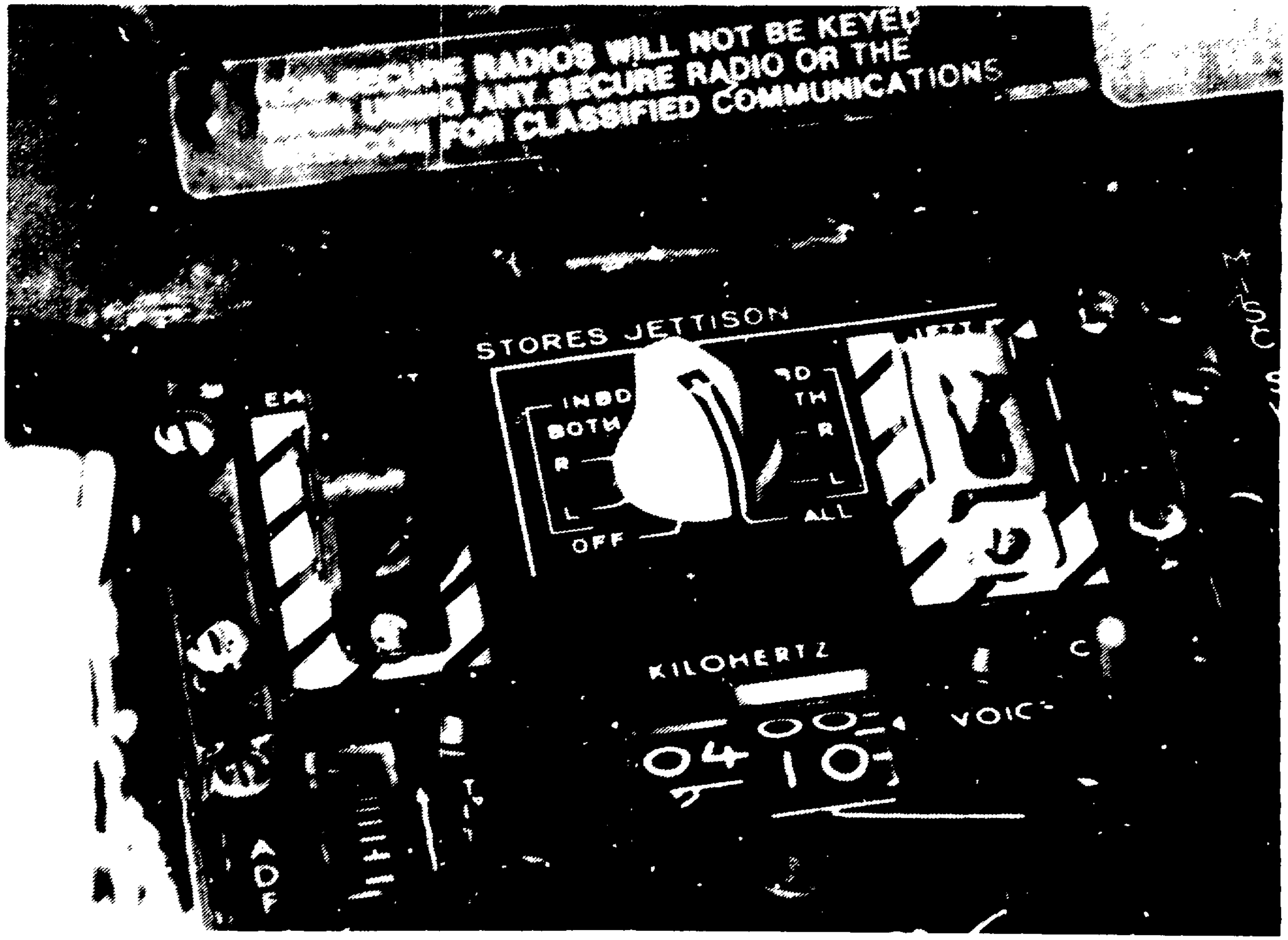

Photo 15. ESSS Interface Control Panel Installed in Cockpit Center Console (Forward Left Corner Location)

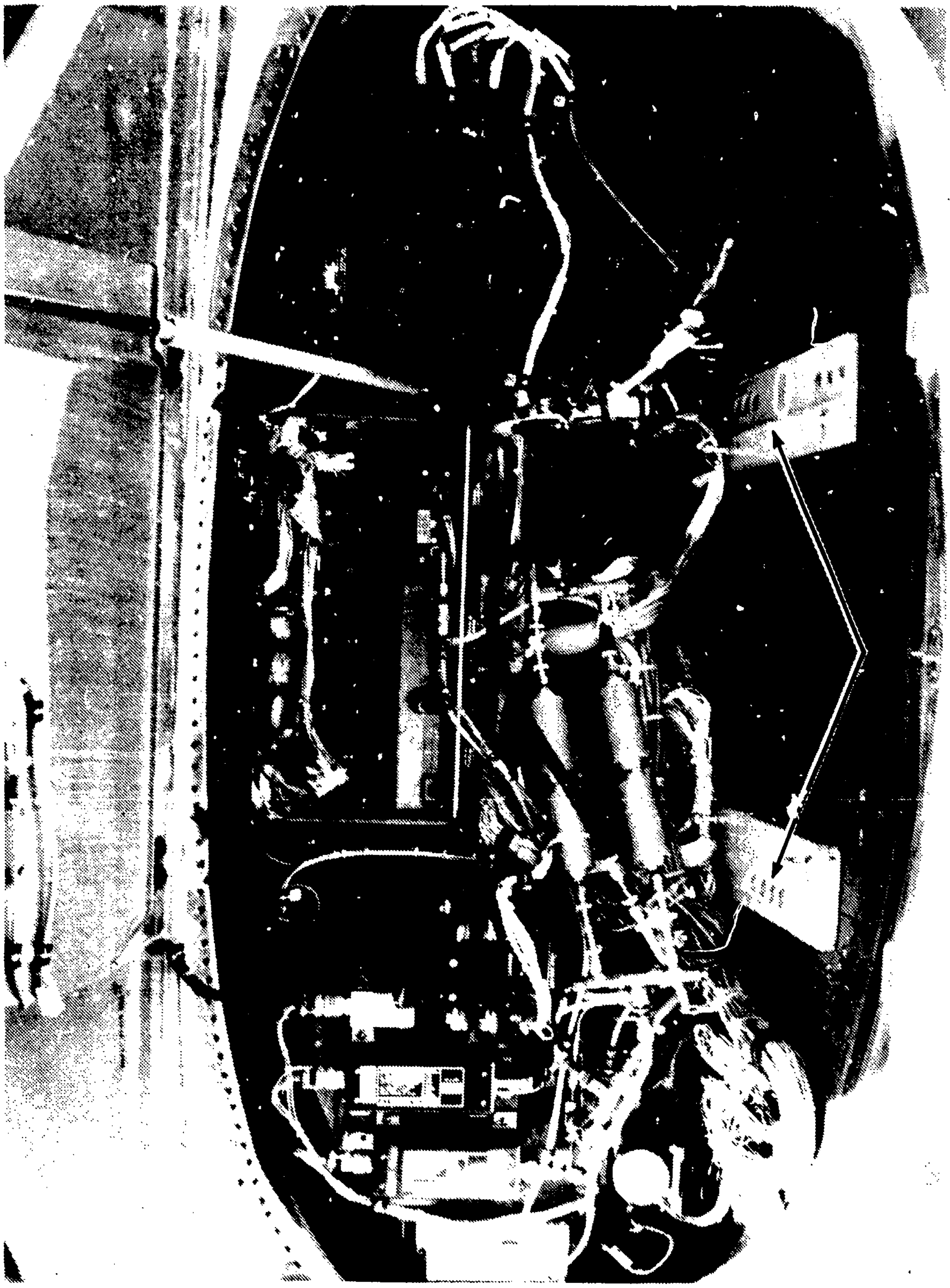

Photo 16. Nose Bay Ballast Mounting Location

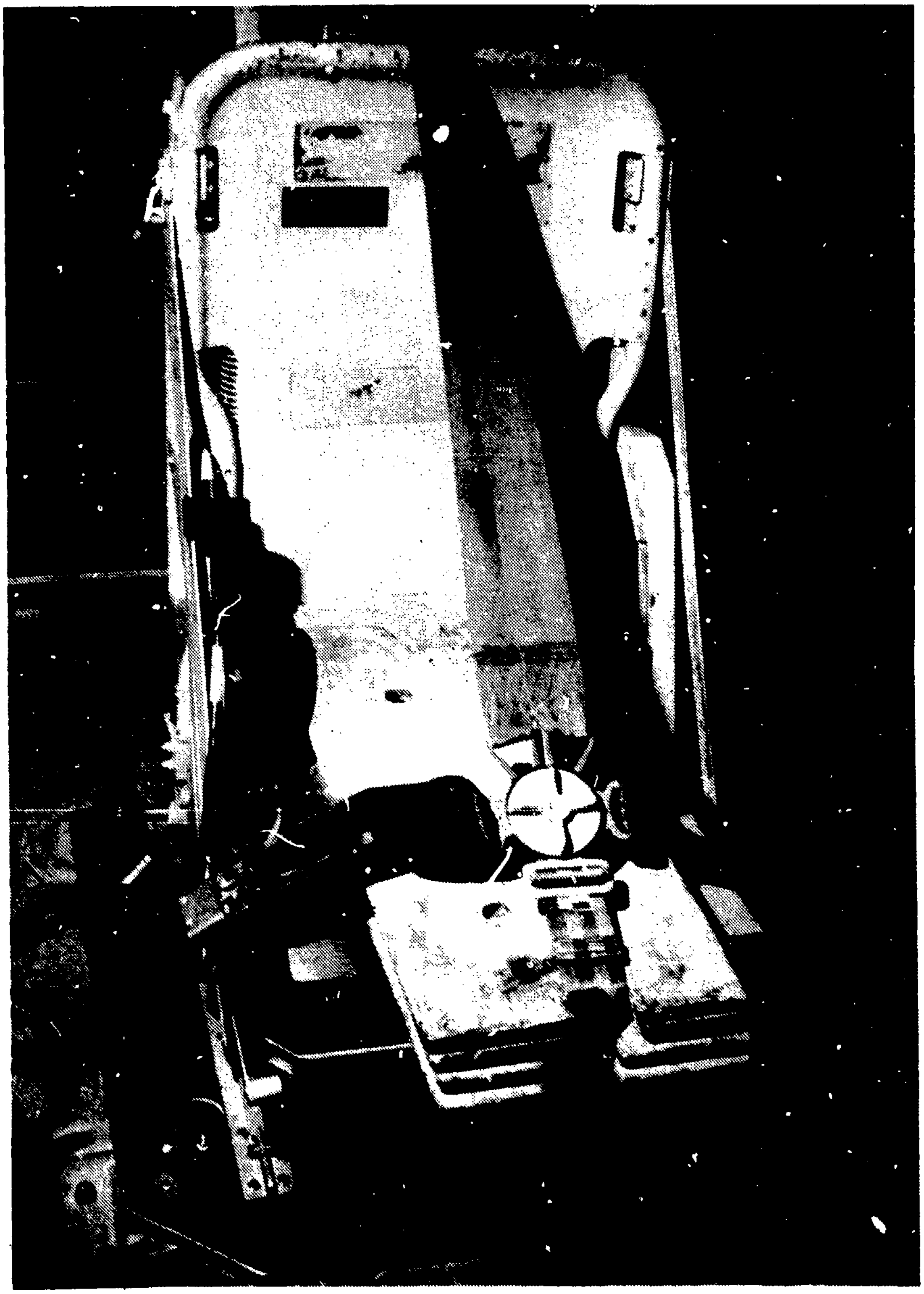

Photo 17. Observer's Seat Ballast Mounting Location

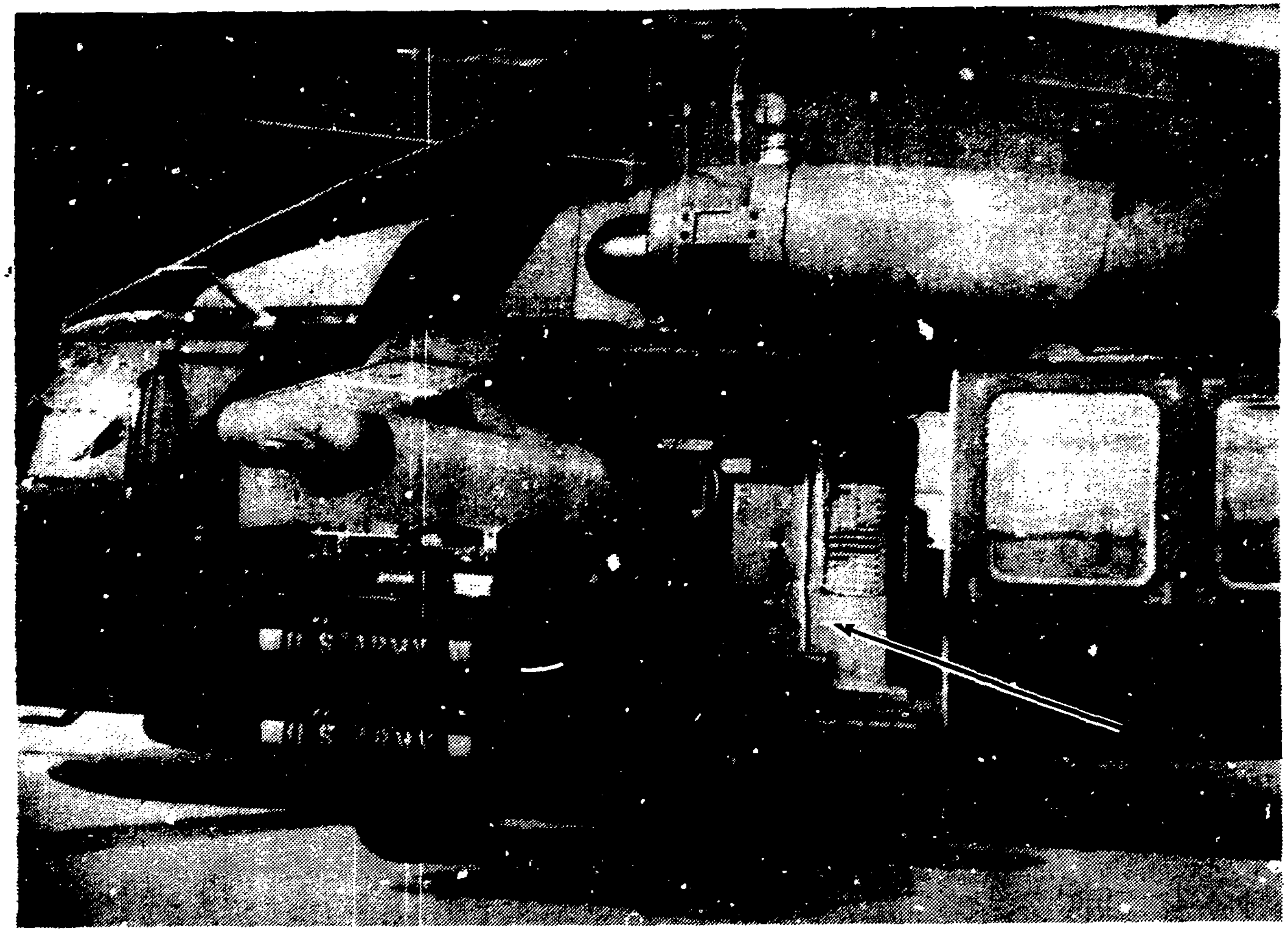

Photo 18. Left View of Test Instrumentation Installation

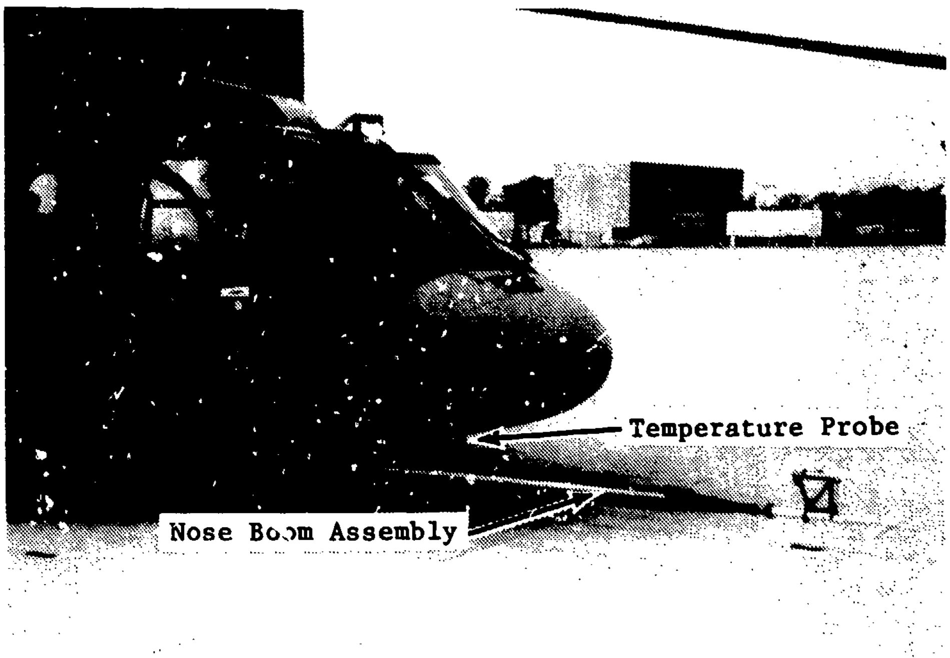

Photo 19. Boom System Installation and Nose-Mounted Temperature Probe

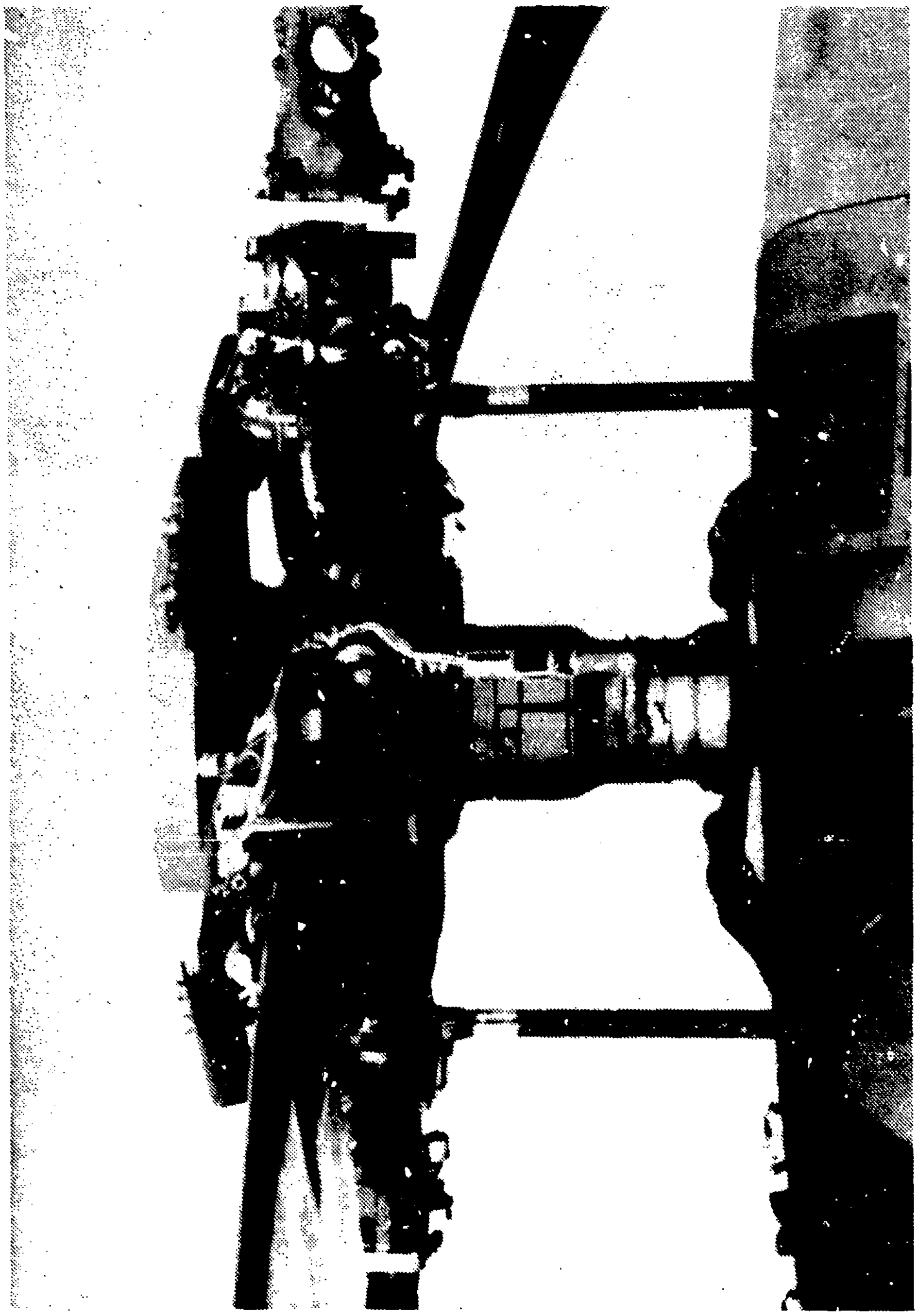

Photo 20. Main Rotor Slip Ring Assembly

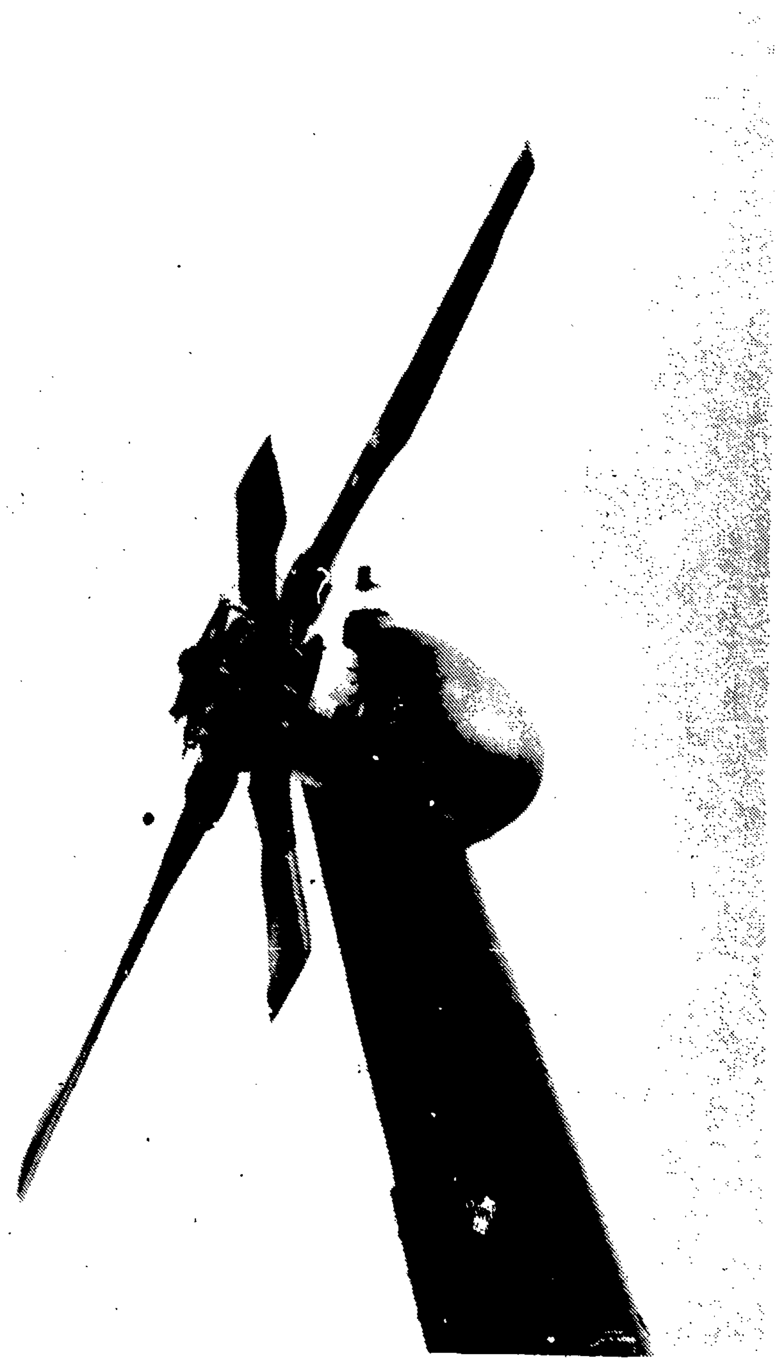

Photo 21. Tail Rotor Slip Ring Assembly

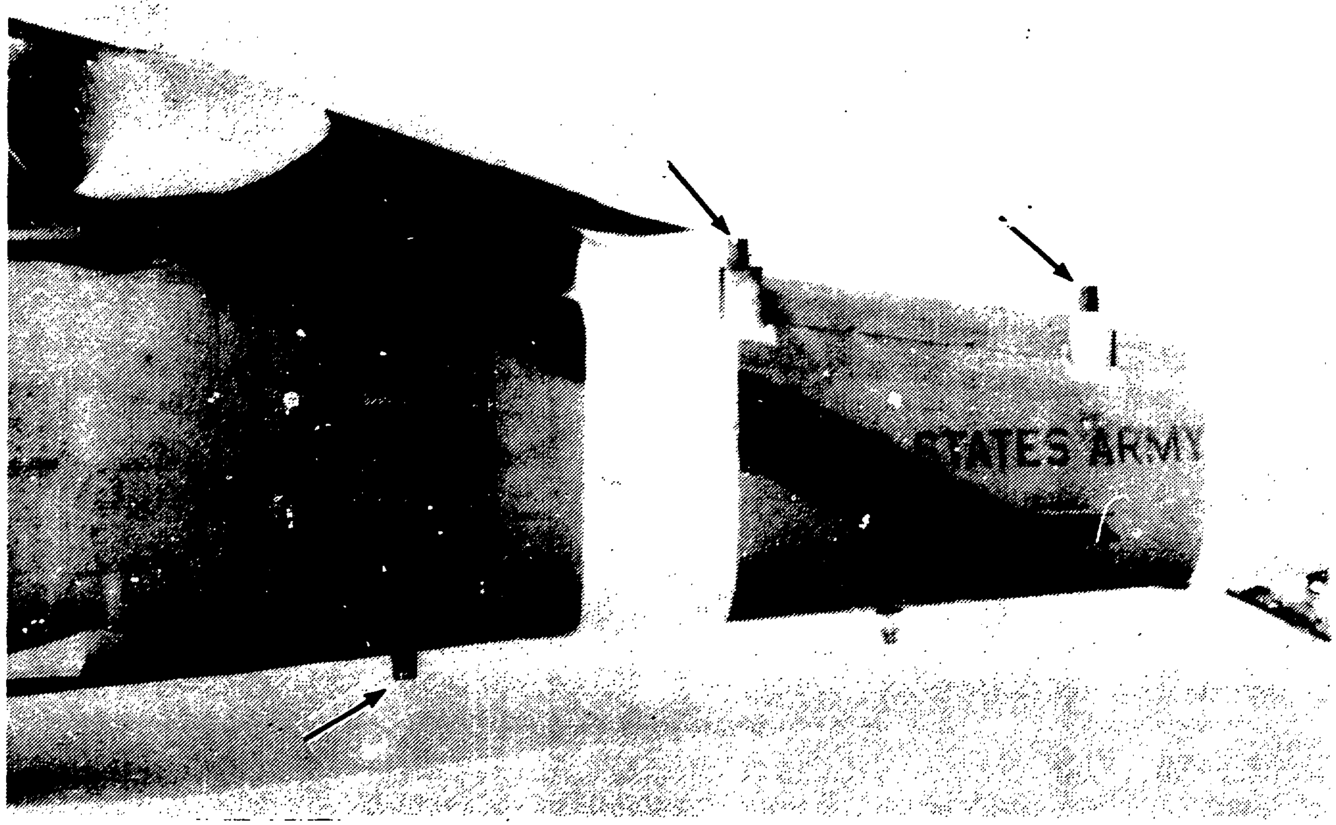

Photo 22. Tail Boom and Belly-Mounted Telemetry Antennas

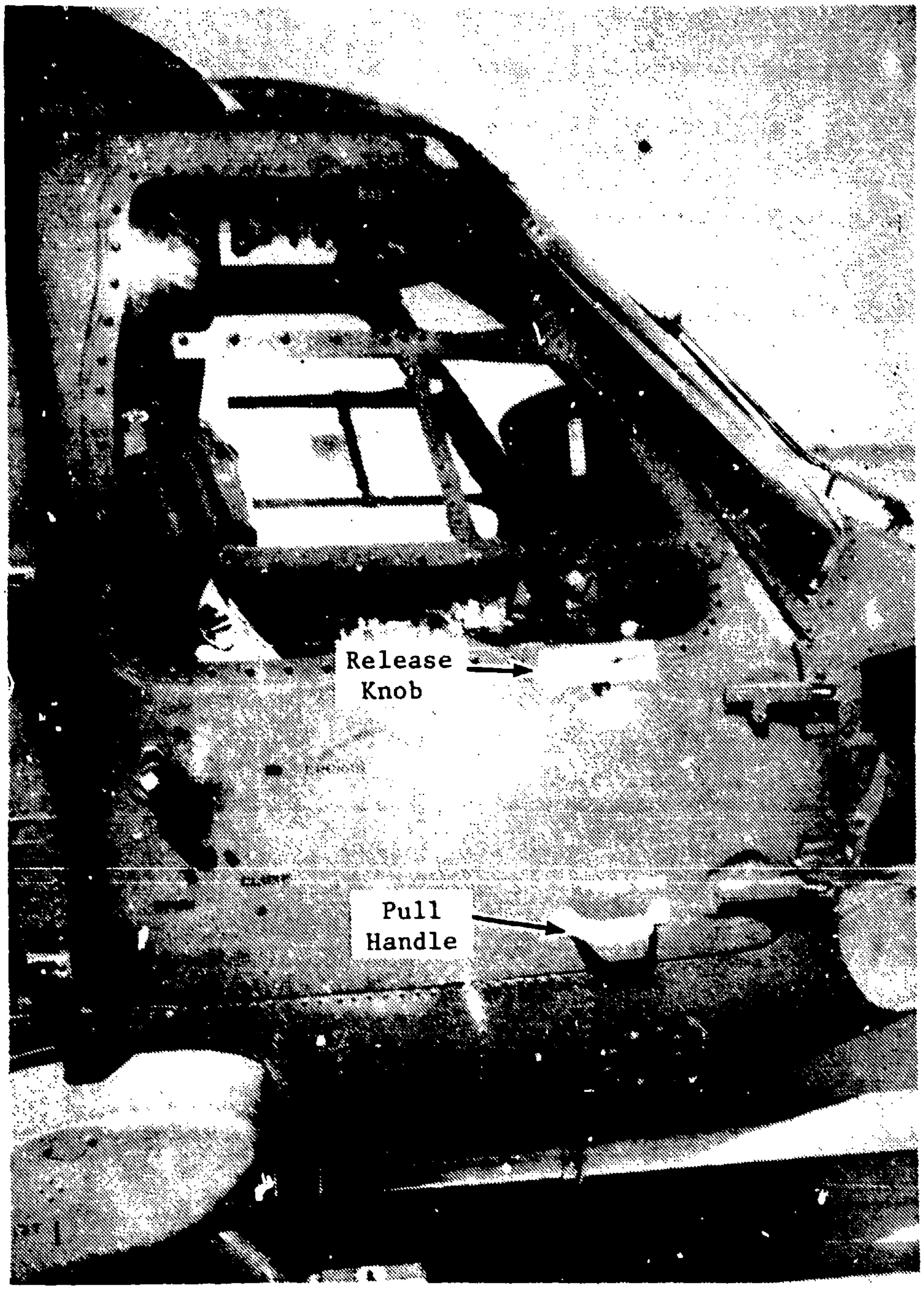

Photo 23. Emergency Crew Door Handles

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US Army Training and Doctrine Command (ATCD-T, ATCD-B)	2
US Army Aviation Systems Command (AMSAV-8, AMSAV-Q, AMSAV-MC, AMSAV-ME, AMSAV-L, AMSAV-N, AMSAV-GTD)	8
US Army Test and Evaluation Command (AMSTE-TE-V, AMSTE-TE-O)	2
US Army Logistics Evaluation Agency (DALO-LEI)	1
US Army Materiel Systems Analysis Agency (AMXSY-RV, AMXSY-MP)	8
US Army Operational Test and Evaluation Agency (CSTE-AVSD-E)	2
US Army Armor School (ATSB-CD-TE)	1
US Army Aviation Center (ATZQ-D-T, ATZQ-CDC-C, ATZQ-TSM-A, ATZQ-TSM-S, ATZQ-TSM-LH)	5
US Army Combined Arms Center (ATZL-TIE)	1
US Army Safety Center (PESC-SPA, PESC-SE)	2
US Army Cost and Economic Analysis Center (CACC-AM)	1
US Army Aviation Research and Technology Activity (AVSCOM) NASA/Ames Research Center (SAVRT-R, SAVRT-M (Library)	3
US Army Aviation Research and Technology Activity (AVSCOM) Aviation Applied Technology Directorate (SAVRT-TY-DRD SAVRT-TY-TSC (Tech Library)	2

US Army Aviation Research and Technology Activity (AVSCOM) Aeroflightdynamics Directorate (SAVRT-AF-D)	1
US Army Aviation Research and Technology Activity (AVSCOM) Propulsion Directorate (SAVRT-PN-D)	1
Defense Technical Information Center (FDAC)	2
US Military Academy, Department of Mechanics (Aero Group Director)	1
ASD/AFXT, ASD/ENF	2
US Army Aviation Development Test Activity (STEBG-CT)	2
Assistant Technical Director for Projects, Code: CT-24 (Mr. Joseph Dunn)	2
6520 Test Group (ENML)	1
Commander, Naval Air Systems Command (AIR 5115B, AIR 5301)	3
Defense Intelligence Agency (DIA-DT-2D)	1
Headquarters United States Army Aviation Center and Fort Rucker (ATZQ-ESO-L)	1
School of Aerospace Engineering (Dr. Daniel P. Schrage)	1
Commander, US Army Aviation Systems Command (AMSAV-EA, AMSAV-EC, AMSAV-ES)	4
Project Manager, Black Hawk (AMCPM-BH-T)	4